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ABSTRACT

Forty-five students divided into six experimental groups were given a programed presentation using teaching machines, which included different feedback procedures. The most efficient feedback procedure was that of administering a specific review until the criterion frame performance was correct. The least efficient procedure was that of repeating the previous presentation as many times as necessary until a correct performance was achieved. In a second experiment, one hundred and sixty school children in the second, third, and fourth grades demonstrated that although the hierarchy of concepts was logical it did not represent the skills in a sequence acquired by these children. Two related studies were also included although they were not a part of the project's proposal. The first investigated various combinations of right-wrong knowledge of results on conceptual learning. The results indicated that knowledge of results did not facilitate learning of the concept acquisition task. The second study examined the effect of the amount of negative knowledge of results upon naming of fractional amounts. Students receiving only the correct responses on the first trial showed significantly fewer errors in subsequent trials than the group which was given four alternative responses but no knowledge of responses on the first trial. (RR)

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March 1969

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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FEEDBACK AND REMEDIAL INSTRUCTION IN LEARNING HIERARCHICAL TASKS

1. Specific Review vs. Repeated Presentation in a Programed Imaginary Science
2. Various Combinations of Right-Wrong Knowledge of Results in Conceptual Learning
3. Amount of Negative Knowledge of Results in Naming Fractional Amounts

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Brigham Young University
Provo, Utah

March 1969

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Graduate students who assisted with this research include the following: Caroline Genovese prepared much of the fractions program and conducted the task analysis research. Kieth Barton supervised the preparation of the Xenograde films. Larry E. Wood prepared the computer program described in Appendix B and conducted Study 1 using the fractions program. Karl E. Starr conducted Study 2 using the fractions program. Brook Noall supervised the data collection and analysis of Experiment 1 and assisted with preparation of the final report.

The following persons each went the extra mile in completing various portions of this research: Helen King, Virginia Smith, Joy Halmotaller, Barbara Champlin, Lynn Cowan, Janis Griffith, Kay Hansen, and Frances King.

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INTRODUCTION

This report consists of several sections as indicated in the table of contents. Figures and tables related to a given section of the report are numbered from 1 to N within the section. These figures and tables appear following the text for each section and are printed on yellow paper to facilitate the reader's locating this information.

Several appendices are attached following the report. These contain information which is supplementary to the material contained in the body of the report. To facilitate location, each appendix is printed on a different color paper.

Introductory material to each section of this report is found in the respective section where it is relevant.

The contract called for two experimental studies. The first, indexed as Experiment 1 in the table of contents, was completed as proposed. The second, Experiment 2, was not completed as proposed because of difficulties explained in the section indexed as "Departure from proposal." Additional material included in this report, either directly or indirectly related to this project, in clude: Study 1 conducted by Larry E. Wood; Study 2 conducted by Karl E. Starr; and the computer program for analyzing data tapes.

SUMMARY

Experiment 1 " Specific review vs. repeated presentation in a programed imaginary science."

Forty five Ss were given a programed presentation of the Imaginary Science of Xenograde Systems using Autotutor teaching machines attached to a Technirite 20 channel inkless recorder. Ss were randomly divided into six experimental conditions as follows: Group I received no knowledge of results on criterion frame performance; Group II received right-wrong information; Group III repeated previous presentation once when performance on criterion frame was incorrect; Group IV repeated previous presentation as many times as necessary until criterion frame performance was correct; Group V received a specific review once after incorrect criterion frame; Group VI received specific review until criterion frame performance was correct. Results showed Group VI to be the most efficient procedure, with Group IV being least efficient. No error differences were observed.

Fractional concepts task analysis

Two hierarchical sets of skills were identified, the first based on a set analysis of being able to name a fraction and the second on a simple fraction to complex fraction analysis. The children investigated in regard to the set analysis demonstrated that the hierarchy, while logical, did not represent the skills in a sequence acquired by these children. The simple to complex sequence, on the other hand, was verified by data from 160 school children in the 2nd, 3rd and 4th grades. At grade

2, 60% of the children know the concept 1/2, while only 25% were able to understand 1/3 and 1/4. Only one child knew non unit numerator namer fractions at this level. By grade 3, 60% were able to answer unit namer questions and 40% non unit namers. By grade 4, 90% knew unit namers and 70% knew non unit namers. In every case, parts of a whole object were easier problems than parts of a collection of objects.

Study 1 "Various combinations of right-wrong knowledge of results on conceptual learning."

Thirty-five Ss were randomly assigned to five treatment conditions. The independent variables investigated were feedback for correct and incorrect responses, feedback for correct responses only, feedback for incorrect responses only, and no feedback for either of the responses.

The results indicated that knowledge of results did not facilitate learning of the concept acquisition task. However, the results were inconclusive because none of the experimental groups showed a significant amount of learning.

Study 2

Twenty 2nd grade Ss were presented 15 multiple choice questions which required S to recognize the correct name of fractional amounts. The set of 15 questions was repeated three times. The independent variable was number of response alternatives on trial number 1. Ss were divided into five experimental groups where group 1 received only the correct response; group 2, two alternatives; group 3, three alternatives; group 4, four alternatives; and group 5, four alternatives but no K of R on trial 1. Ss were allowed to respond until they found the correct answer on all trials. Questions were presented on a switch box device where a green or red light indicated correct or incorrect response as soon as S flipped a switch indicating his answer. Results showed group 1 made significantly fewer errors on trials 2 and 3 than any other group. Group 5 made more errors than any other group. The results replicate a Kaess and Zeaman (1960) study with college students but may indicate the result is a function of the experimental situation and does not necessarily depend on understanding the material.

SPECIFIC REVIEW VS. REPEATED PRESENTATION IN A PROGRAMED IMAGINARY SCIENCE

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Crowder (1960) and the producers of Tutor Texts and Autotutor teaching machines [1] have made extensive use of a return procedure in which S, upon making an error, is returned to the previous presentation where he is instructed to re-read the material and to try the question a second time. This return procedure is usually coupled with a correction procedure, which requires the student to continue to return until the correct answer is chosen.

The purpose of the present study was to compare specific review (see Merrill, 1965; Merrill and Stolurow, 1966; Merrill, 1970) with a return procedure typical of that used by Autotutor and Tutor Texts. In addition, this research compared a single return or review presentation with the correction procedure.

During the preparation and validation studies of the program first used by Merrill (1965), it was found that when Ss were asked to re-read material previously presented they complained that this procedure was not beneficial and requested further explanation. On the basis of this experience, General Review and Specific Review were the procedures included in the 1965 study, rather than the more common return procedure. Subsequent research (Merrill and Stolurow, 1966; Merrill, 1970) demonstrated the effectiveness of Specific Review and the ineffectiveness of General Review under conditions where the review carried the instructional load and where it merely supplemented more extensive programing. Based on this experience, it was hypothesized that:

1. Ss who are returned to previous presentations when they make errors on a criterion frame will make more errors on the test and will take more time to learn than Ss who are given a specific review.

One group in the Merrill and Stolurow (1966) study was identical to a control group in the Merrill (1970) study, except that the Merrill (1965) group represented a correction condition while the Merrill and Stolurow (1966) group was given two kinds of review, but then was allowed to proceed whether or not the third try was correct. A comparison of the mean scores of these two groups indicated no significant difference. Based on this somewhat tenuous finding, it was hypothesized that:

2. Ss who are returned to previous presentations or presented a specific review until they make the correct response (correction) will not make fewer errors on the test but will take more time to learn than Ss who are returned or reviewed only once.

Ausubel (1963) hypothesized that mastery of previous parts in a hierarchical task promotes facilitation in learning subsequent parts. While Merrill (1965) failed to support this prediction, a subsequent replication (Merrill, 1970) did partially support Ausubel's prediction. Based on this evidence, it was hypothesized that:

3. Ss who receive specific review or who are returned to previous presentations will make progressively fewer errors and take progressively less time on each succeeding lesson than Ss who do not receive remedial instruction.

Method

Materials

Content. The Science of Xenograde Systems, a complex imaginary science, served as the learning task for this study. The science describes a closed system consisting of three satellites orbiting a nucleus which contains small particles called alphons. A series of five lessons instructs S in the procedure necessary to predict the location and speed of the satellites at specified intervals of time. The task has a hierarchical structure in that understanding principles presented in later lessons depends on understanding prerequisite principles contained in previous lessons. The method of analysis used to identify this structure and a more detailed description of the content of this science are contained in previous reports (Merrill, 1964, 1965).[2]

Program. The content of the science was presented to each S by means of branching programed instruction. The program was presented in a series of five lessons. Lessons 1 and 2 required approximately 30 minutes each and Lessons 3, 4, and 5 required approximately one hour each. Each lesson consisted of a series of four or five concepts and/or principles. Each of these concepts and/or principles was taught with a branching sequence similar to that illustrated in

Figure 1. P frames (P_1, P_2, and P_3) are presentation frames. These frames provided definitions, explanations, and examples, and then tested S's comprehension by asking a multiple choice question. None of these questions could be answered by merely filling in a blank or looking back to the explanation for the missing word; rather, these questions presented S with a new example and asked him to identify the concept or to apply the principle in finding the answer. The questions on each of the P frames in a given sequence were all related to a single concept or principle. F frames (F+ or F-) are feedback frames. These frames merely had the words "You are correct" (F+) or "You are incorrect" (F-), plus the directions "Push button X," which would move S to the next frame. Q frames (Q_1) are criterion question frames. Whereas the question asked on each of the P frames may have required S to apply only part of the principle involved, the Q frame question was a comprehensive question requiring S to apply the entire principle plus principles taught in previous sequences to a new example. In some sequences there were two Q frames rather than a single question. In these sequences S was branched to the appropriate experimental procedure if he missed the first question or if he got the first question correct and then missed the second question. When S was correct on the [illegible] frame, he was branched immediately to the next sequence in the lesson. When he was incorrect, he received one of the six experimental treatments described in the procedure section of this report. In previous research (Merrill 1965, 1970), the Q frames for a given lesson were given as a quiz after all

of the P frames. This program varied that sequence by inserting each Q frame immediately following the P frames to which it was most relevant.

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Insert Figure 1 about here
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Apparatus

The programed materials were presented to Ss on Autotutor Mark II teaching machines.[3] The program was recorded on black and white, 35 mm, high contrast film and was projected to S on a high contrast, rear-projection lenscreen (9.6 inches high by 7.0 inches wide). When directed to do so, S responded to the material on the film by pushing one of ten buttons which were located to the right of the viewing screen. Depending on which button was pushed, the film moved an odd number of frames forward (1, 3, 5, ... , 15) corresponding to buttons A-H, 19 frames backward for button I, or returned to the previous frame for button R. This procedure allowed a semi-random access to the materials on the film.

Each button of the Autotutor was connected to one channel of a Techni-rite 20 channel inkless event recorder.[4] The Techni-rite recorder consists of 20 separate styluses which write by means of heat and pressure on specially-coated chart paper which moves over a knife edge writing surface. The chart paper moves under the styluses at a constant speed of 2.5 inches per minute. The recorder will accept 20 separate channels of "on-off" information. When DC voltage is applied to the pen motor the stylus is instantly deflected into a calibrated position of the chart paper. When the voltage is removed the pen motor returns the stylus to the uncalibrated position of its channel on the chart paper. The Autotutors were connected to the recorder so that pushing a button on the Autotutor caused an electrical impulse which deflected a pen on the recorder. The electric potential remained on until the next button was pushed. The pen which was deflected indicated which button was pushed. The distance between deflections indicated time between button presses and therefore gave a record of latency for each frame of the program. Two Autotutors were attached to a single recorder, the ten buttons of one attached to the first ten channels of the recorder and the second to the other ten channels of the recorder. Interpretation required beginning with the first frame seen by S and keeping track of his progress by comparison with the instructional program.

Interpretation of response charts and tabulation of data was accomplished as follows: a A key punch operator transcribed the data contained on the charts directly to punched cards. At this point no interpretation was necessary; the operator merely punched the number of squares between pen deflections on the calibrated portion of the response chart (latency) and the number of the channel into which the stylus was deflected. b The data cards were then interpreted by a computer program which compared each response with a table representing the instructional program. This table indicated for each frame of the film which responses were possible and which response was correct. By noting the response pushed by S, the computer could determine the frame in the table which corresponded to the response data. If the response data indicated an inappropriate response, one not indicated in the table, an error message was printed and the data cards were again compared with the original data. This provided a check on punching errors. The computer program also compiled appropriate summaries of the data so that the output was in a form ready for analysis. The above procedure minimized the chance for errors both in interpretation of response records and in summarizing the data.

The data was collected in the Laboratory for the Experimental Study of Instruction at Brigham Young University. Ss were seated in adjacent language laboratory carrels constructed of sound resistant materials. An Autotutor, paper and a pencil were located in each carrel. The recorder was located on a table several feet in front of the carrels. When seated at the teaching machines, S could not see the recorder. This table also contained extra films, data records, and other necessary materials. The laboratory was located next to a reception area for several faculty offices and, while not completely removed from office noise, was restricted so that the only obvious interruption was placing another S on an adjacent machine.

Subjects

Forty five Ss (14 males and 31 females) volunteered to participate in this study. All Ss were students enrolled in undergraduate educational psychology classes at Brigham Young University. Some of the Ss were given the option of participating in the study or doing readings as part of their course requirements. Others were encouraged to volunteer but were given no added incentive except for the advancement of science. Of the original 45 volunteers, six failed to complete the study and were excluded from the final analysis. Two of these came from Group VI and one each from Groups II through V. To equalize the cell sizes, three other Ss were randomly excluded from the final analysis, one each from Groups I, III and IV. Of the 36 Ss included in the final analysis, 30 ranged in age from 21 to 25 years with the median age being 22. There were six older Ss, four in the 25 to 30 year range, and two over 35. Of these older Ss, two were in Group VI, two in Group III, and one each in Groups II and V. The teaching majors of the 36 Ss were as follows: five foreign language, three English, three social studies, four life science, one math, one business education, thirteen elementary instruction, one music, and five physical education.

Procedure

Administrative. Each S participated in from three to five sessions. These sessions varied from 30 minutes to 2 1/2 hours in length. For a given S all sessions were completed within a seven day period of time. All sessions were conducted in the laboratory during the hours from 8:00 a. m. to 6:00 p. m. All sessions were supervised by a receptionist or a graduate student who was available for questions or in case of machine malfunction. Reliability of data collection was extremely high, in that only two machine malfunctions occurred during the entire data collection process. In both of these cases, S experienced a delay of two or three minutes and was then allowed to continue his study of the program. Questions about content were always answered by encouraging S to reread the frame on which he was working and then to proceed.

All Ss who volunteered to participate were instructed to come to the laboratory and register. The registration sheet requested the following data: name, address, phone number, age, sex, and teaching major. Opposite each name was an ID number used for identification purposes throughout the study. These ID numbers consisted of a study number, a group assignment number, and an individual sequence number. The group numbers were randomly arranged on the sign-up sheet so that each S was randomly assigned to an experimental group and each group of six Ss registering consisted of a single replication with one S in each group. After signing the registration sheet, Ss scheduled five hours of time, in one or two hour blocks, within a seven day period.

When S returned to participate in the scheduled session he entered his name, ID number, the lesson to be learned, and the date on a sign-in sheet. These sheets each contained a data tape number and provided an index of where the data on each lesson for each S appeared on the data tapes. The receptionist checked the S's original ID against the ID entered on the sign-in sheet, selected the appropriate film and lesson, prepared the teaching machine, and then recorded the S's ID number, the date and the lesson number on the data tape. S was then seated at the teaching machine and allowed to continue until one or two lessons, as previously scheduled, were completed. Ss were requested to complete a given lesson in a single session rather than stop in the middle of a lesson. There was only one exception to this request; one S was unable to complete a lesson in the scheduled time and, because of another appointment, stopped in the middle of Lesson 4. When she returned to the lab the machine was started in the middle of Lesson 4. Several Ss required more than the scheduled time for a given lesson but the usual procedure was for them to continue working until a lesson was completed.

Treatment. Each S was randomly assigned to one of six treatment groups. Figure 2 presents a series of flow charts illustrating the procedure for each treatment condition.

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Insert Figure 2 about here
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When S responded correctly on a Q frame he was sent immediately to the next P frame sequence. Branching occurred only when S was unable to respond correctly to the P frame. Consequently, treatments were different only when Ss made Q frame errors.

Group I (Control). Ss in this group were given no knowledge of results (K of R) concerning their performance on Q frames. In

Figure 2A the box F(+) symbolizes for this group a frame which presented the words "Push button *X*" (where *X* could be any letter from A to H necessary to advance the film to the next P frame sequence.) For this group the box F(-) symbolizes a frame which also presented only the words "Push button *X*."

Group II (Feedback). *Ss* in this group were given only right/wrong K of R concerning their performance on the Q frame. In Figure 2A the frame represented by box F(+) presented the words "You are correct. Push button *X*." The F(+) frame was the same for all of the other groups except Group I and was always the frame presented when *S* was correct on the Q frame. The description will not be repeated for the remaining groups. F(-) presented the words "You are incorrect. Push button *X*."

Group III (Return). *Ss* in this group received frame F(-) --RETURN when they responded incorrectly on their first try at the Q frame and were returned to the beginning and required to repeat the P frame sequence. (See Figure 2B.) This F(-) frame presented the words "You are incorrect" and then indicated that to assist *S* in understanding the material the previous presentation would be repeated. *S* was then instructed to push buttons which branched him back to the P frame sequence. If *S* missed the Q frame on the second try, he was given an F(-) frame as described for Group II and branched to the next P frame sequence.

Group IV (Return/Correction). *Ss* in this group received exactly the same procedure as that described for Group III except that they were branched back to the P frame sequence each time they missed the Q frame question until their responses were correct.

Group V (Specific Review). Figure 2C illustrates the procedure for Group V and Group VI. Ss in the specific review group (V) received frame F(-)--SPECIFIC REVIEW the first time they missed the Q frame question. This frame contained the words "You are incorrect. Below is some material which should help you understand why you missed this question." A specific review then followed. This procedure was briefly described in Merrill (1965, 1970) and was described in detail with an example from the program in Merrill and Stolurow (1966). Briefly, it consisted of a step-by-step explanation of the solution to the problem without completing the final step. S was then returned to the Q frame and required to try again. If he missed the question on the second try he was presented an F(-) frame as described for Group II and branched to the next P frame sequence.

Group VI (Specific Review/Correction). Ss in this group received exactly the same procedure as that described for Group V except that they were again presented the F(-) --SPECIFIC REVIEW frame for two or more incorrect responses until their responses to the Q frames were correct.

Design. Hypotheses one and two were tested by means of a 2 X 2 factorial design with presence vs. absence of correction as one variable and return vs. review as the other variable. Dependent variables were errors and time on the terminal test and total time to learn.

Hypothesis three was tested by means of the repeated measure design illustrated in Figure 3. The analysis procedure used was that described by Lindquist (1953) as a type III mixed design. Comparison of performance within each lesson was accomplished by orthogonal comparisons as described in Edwards (1962). Dependent variables were mean time and mean errors per P frame and mean time and mean errors per Q frame.

Results

The first hypothesis predicted that SR groups would perform more accurately and efficiently than Return groups on the final test. Table 1 indicates the mean percent errors, mean time per frame in seconds, and mean total time in minutes on the final test. The differences between various sets of means on this test was compared using 1 X 6 analysis of variance and orthogonal comparisons as illustrated in Table 2. This set of comparisons provided tests of the following independent variables: Return (Groups III and IV) versus Specific Review (Groups V and VI); Correction (Groups III and IV) versus No Correction (Groups IV and VI); Interaction of Correction with Return and/or Specific Review; Control (Group I) versus Feedback (Group II); and Control-Feedback combined (Groups I and II) versus experimental groups (III - VI) combined. For the three variables included in Table 1, none of these comparisons were significant ($p < .05$). The interaction for total time and time per frame, however, approached this significance level and when interpreted with the learning data does provide some useful information. (For total time; $F = 2.31$, $p > .10 < .15$. For time per frame; $F = 3.24$, $p > .05 < .10$). An examination of the means in Table 1 for both of these variables indicated that when Correction was combined with Specific Review during learning the time required per question and for the whole test was less than when Correction was combined with Return. However, when No Correction was used during learning, Return was more efficient than Specific Review. Considering the data and the agreed significance levels, hypothesis one was clearly not supported for errors on the final test and not adequately supported for time to complete the test. It is important to note that the control conditions performed as adequately as the experimental groups on the test variables.

Hypothesis number two predicted that Ss in Correction conditions would perform more efficiently than Ss in No Correction conditions. For total time to take the test and for time per question on the test, this hypothesis was not supported. The interactions described in the previous paragraph which approach significance may indicate that the efficiency of a Correction procedure depends to some extent on the other review conditions with which it is coupled.

Hypothesis number three predicted a cumulative transfer effect favoring the experimental conditions for both errors and efficiency as Ss proceeded through the lessons. There were a number of dependent variables which could have been examined for evidence to test hypothesis number three as well as the learning efficiency predictions of hypotheses one and two. The following are presented here: (1) total time to complete each lesson and all five lessons combined was derived by summing the time in seconds spent on every frame in the program, including repeated frames. This figure should be accurate to plus or minus .10 minutes. (2) Mean time per P frame, in seconds, accurate to plus or minus 2.5 seconds was derived by summing the time spent on each P frame in a given lesson and dividing by the number of frames in the lesson. This measure was a mean of time spent on first exposure to a P frame. Data on subsequent repetitions of P frames (Groups III and IV) were cumulated separately and were included in this score. (3) Mean time per Q frame in seconds, accurate to plus or minus 2.5 seconds as with P frames, included only time spent on first exposure to Q frames; it did not include time spent when Q frames were repeated (Groups V and VI). (4) Percent errors on P frames for a given lesson was derived by dividing the number of P frame errors by the number of P frames in a given lesson. This variable included only the first time S responded to a given P frame. Data on subsequent repetitions of P frames for Groups III and IV were cumulated separately. (5) Percent errors on Q frames for a given lesson was derived in the same way as P frame errors and included only first exposure data.

Variables were compared using 6 X 5 repeated measure analysis of variance and orthogonal comparisons. The variables tested were the same as those described previously with the following extention: Because there were five lessons, two sets of comparisons were possible; the five degrees of freedom associated with row means (scores collapsed across lessons) were compared using the orthogonal coefficients illustrated in Table 2, and the 20 degrees of freedom associated with the interaction of six treatments and five lessons was used to make these same comparisons interacting with five lessons. The source table illustrated in Table 3 indicates the partitioning done for these comparisons.

Figure 4 illustrates mean total time in minutes required for each group to complete each lesson. Table 3 presents the summary table for the analysis of variance and for each of the orthogonal comparisons. It is evident from Figure 4 that there was no difference on Lessons 1 and 2. However, as learning proceeded, Ss in the Return/Correction group (Group IV) took increasingly more time to complete a lesson than did Ss in the other groups while Ss in the SR/Correction group (Group VI) took increasingly less time. In Table 3, the significant row difference (SR vs. R) and the significant interactions (SR vs. R and INTERACTION) indicates that this difference is significant. It should be noted that Return/Correction Ss were repeating large segments of material and that this time was included in these figures. An even more interesting note is that SR/Correction Ss were also receiving additional material and were being required to get criterion frames correct before proceeding, yet their time was less than that of the control condition Ss who did not receive any extra material.

Figure 5 illustrates the mean time (in seconds) per P frame for each group on each lesson. A set of orthogonal comparisons was made parallel to those reported for total time. Most of the comparisons were not significant, consequently the summary table is not included. The mean difference observed for total time is reflected for time per frame in Figure 5; however, this difference at the per-frame level does not reach significance. There was a significant difference (F = 3.16 with 20/120 df) between the experimental groups combined (Groups III-VI), and the two control groups combined

(Groups I & II) on the orthoginal comparison of this variable as it interacts across lessons. This difference indicates that on time per P frame, control groups take increasingly more time when compared with experimental groups. The low scores for the SR Correction group (Group VI) help to make this difference significant, even though this group is not significantly lower than other experimental groups at the level specified.

Figure 6 illustrates the mean time (in seconds) per Q frame for each group on each lesson. Again, orthogonal comparisons were made as illustrated in Tables 2 and 3. While the per-frame differences observed in Figures 5 and 6 do not reach the specified significance level, they are nevertheless consistent with the differences observed for total time. When these per-frame differences are cumulated and added to time for auxillary information, the total cumulated time difference is significant.

None of the comparisons for the P frame errors or Q frame errors were significant at the specified level.

The previous data do not clearly support hypothesis three as it was stated. There seems to be some evidence that performance is more efficient when SR and Correction were combined, but that none of the conditions consistently improved accuracy of performance. The fact that there was not a consistent difference between control groups I and II and the experimental groups suggests that the conditions as implemented contribute only minimally to the performance on the task.

Discussion

The most pervasive finding of this study is that when coupled with a Correction procedure the SR technique increased the learning efficiency with little effect on error rate. At least two questions are raised by this result; first, why would the Correction procedure require less time when linked with SR and more time when linked with R? Second, why did the SR procedure fail to produce consistent differences from the control groups as has been observed in a previous study (Merrill, 1970)?

The first question has an obvious answer for the total time variable in regard to Correction Return. Failing to answer a criterion question correctly meant that S was required to repeat at least three P frames and frequently more before being allowed to try the criterion question again. Most Ss expressed real frustration when they missed the criterion question and especially when they missed it a second time. Ss in Groups III and IV rushed through the second presentation of P frames much faster than the first try. On the first exposure, mean time per frame across all lessons was 82.2 seconds per frame for Group III and 80.0 seconds per frame for Group IV. The mean time across lessons on the second or more try was 37.7 seconds per frame for Group III and 25.1 seconds per frame for Group IV. Even with this rushing the extra time required was bound to inflate the total time measure, especially for Group IV.

Group VI (Correction SR) Ss, on the other hand, were required to read only one additional frame when they missed a criterion question and to reread this frame until they got the question correct. It is not surprising that their performance required less time than the Return conditions. What is interesting is that Correction SR (Group VI), in which the additional SR frame was read several times, took less total time than SR No Correction (Group V), in which the extra frame was read but once. Apparently the SR frame, when read until it was comprehended, increased the Ss performance speed perhaps by giving him more confidence in his response. This conclusion is supported more strongly for the P frame time data (Figure 5). By receiving SR frames when criterion frames were missed, these Ss apparently gained a feeling of confidence about their understanding of the material on subsequent presentation frames (at least they responded more rapidly).

The review material, whether SR or Return, apparently increased S's confidence about the material as evidenced by the longer latencies of the control groups (I and II) on the subsequent P frames. At least they knew that if they didn't understand, they would receive additional review by repetition or by SR.

The author was surprised that the effects were not stronger until he examined previous research more carefully (Merrill, 1965; Merrill, 1970) and realized that when review was associated with the P frames, the resulting differences were more pronounced than when associated only with criterion quiz (Q) frames. Apparently receiving the review immediately following a presentation frame was better than having to wait for a criterion question. It is hypothesized that were this study replicated with the SR associated with P frames and/or Q frames, the time differences would be even more pronounced and might even produce error differences.

One further comment seems relevant. In the history of several studies on review and feedback procedures in teaching an imaginary science, the author has seldom observed error differences. One of the difficulties is the tremendous variability observed between Ss on their scores. The magnitude of differences required under these conditions is so great that they would be difficult to observe even if they existed. Future studies in this area would do well to select more homogeneous samples and to provide for covariance analysis to reduce some of the within-group variance, hence maximizing the possibility of observing between-group variance.

FOOTNOTES

[1] Tutor Texts and Autotutor teaching machines are prepared under the direction of U.S. Industries, INC., Educational Science Division. Tutor Texts are published by Doubleday. Garden City, New York. Autotutors are manufactured by Welch Scientific Company, Skokie, Illinois.

[2] A detailed description of the construction of this program is contained in Merrill, 1964, which can be obtained from University Microfilms, 1965, No. 23-029. The P frames and Q frames have been deposited with American Documentation Institute. Ordering information is available in Merrill, 1970.

[3] Autotutors are manufactured by Welch Scientific Company, 7300 N. Linder Avenue, Skokie, Illinois. Further information concerning this operation can be obtained by writing for descriptive literature.

[4] Technirite recorders are manufactured by Techni-rite Electronics Incorporated, Techni-Rite Industrial Park, Warwick, R.I. Further information concerning this operation can be obtained by writing for descriptive literature.

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Table 1

Final Test
Means for total time, time per question, and percent errors

Group	Total Time Minutes	Time per Question Seconds	Percent Errors
Control	53.0	42.7	.38
Feedback	56.8	44.9	.41
Return	42.2	33.3	.40
R-Correction	57.7	45.7	.38
Specific Review	56.4	47.7	.29
SR-Correction	47.3	37.3	.33

Table 2

Orthogonal Comparisons for Experimental Groups on Final Test

	Group					
Comparison	I	II	III	IV	V	VI
1. Return vs. Spec. Review	0	0	+1	+1	-1	-1
2. Correction Yes vs. No	0	0	+1	-1	+1	-1
3. Interaction	0	0	+1	-1	-1	+1
4. R/W K of R Yes vs. No	+1	-1	0	0	0	0
5. Experimental vs. Control	-2	-2	+1	+1	+1	+1

Table 3

Summary of Analysis of Variance
and Orthogonal Comparisons for Total Time

	Source	df	MS	F
	Treatment	5	1414.59	1.79
Orthogonal Comparisons	SR vs R	1	3587.23	4.53*
	C vs NC	1	104.90	.13
	Interact	1	2484.30	3.14
	FB vs C	1	327.13	.41
	Exp vs C	1	570.03	.72
	Error 1	30	791.03	
	Lessons	4	16429.85	94.14 **
	Interaction	20	324.12	1.86*
Orthogonal Comparisons	SR vs R	4	673.10	3.86**
	C vs NC	4	42.63	0.24
	Interact	4	569.73	3.26*
	FB vs C	4	95.28	.55
	Exp vs C	4	239.96	1.38
	Error 2	120	174.52	
	TOTAL	179		

* $p < .05$

** $p < .01$

FIGURES

Fig. 1. Flow chart illustrating instructional sequence for all groups. P = presentation frame, F(-) = feedback frame incorrect, F(+) = feedback frame correct, Q = criterion question frame.

Fig. 2. Flow chart illustrating sequence for experimental conditions. A for Groups I and II, B for Groups III and IV, C for Groups V and VI. P = presentation frame, F(-) = feedback frame incorrect, F(+) = feedback frame correct, Q = criterion question frame, 1 and 2 indicates procedure after first and second exposure respectively.

Fig. 3. Experimental design used to test hypothesis 3.

Fig. 4. Total time in minutes to complete each lesson for each experimental group.

Fig. 5. Mean time spent per P frame in each lesson for each experimental group.

Fig. 6. Mean time spent per Q frame in each lesson for each experimental group.

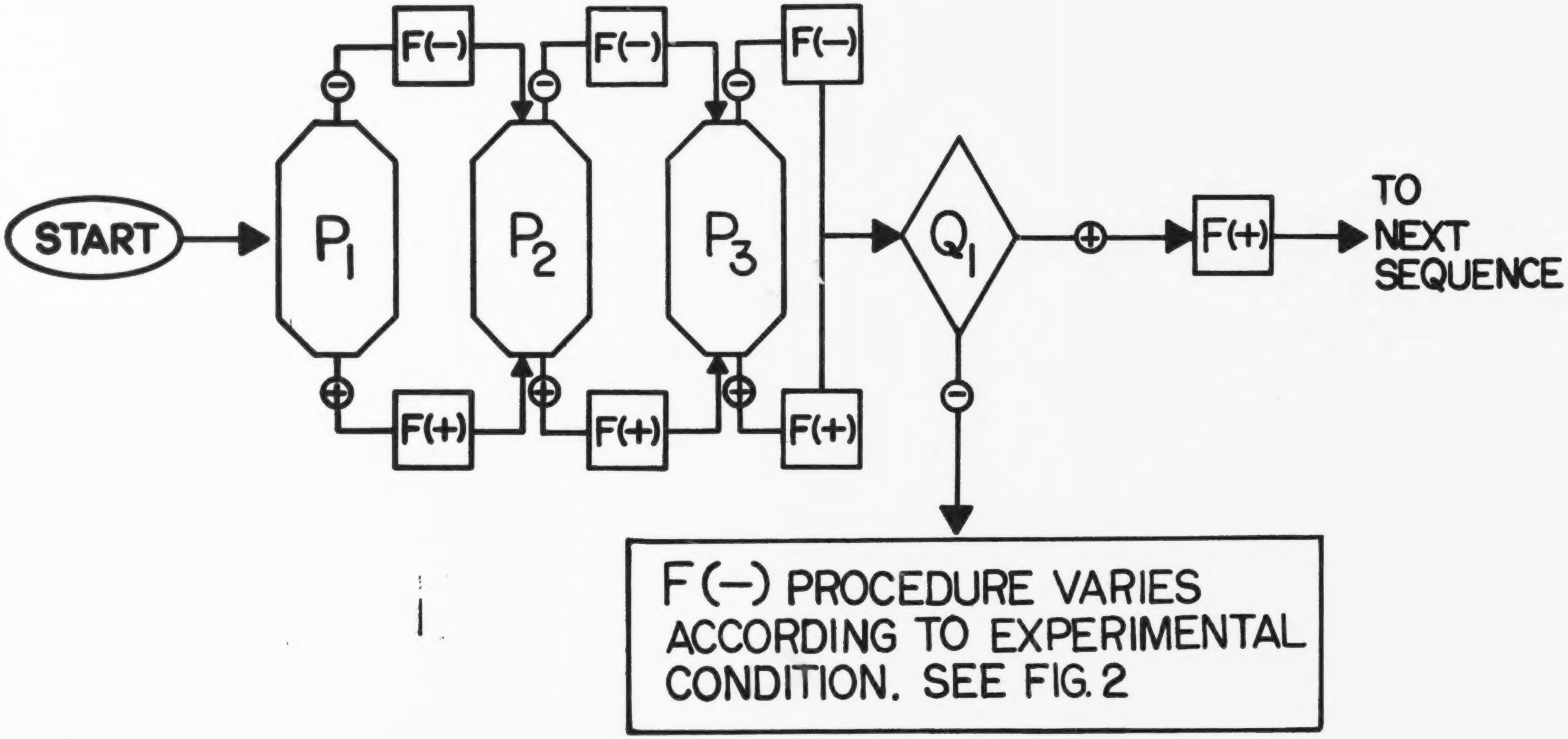
START
P1
P2
P3
F(–)
F(–)
F(–)
F(+)
F(+)
F(+)
Q1
⊖
⊕
F(+)
TO NEXT SEQUENCE
F(–) PROCEDURE VARIES ACCORDING TO EXPERIMENTAL CONDITION. SEE FIG. 2

Fig. 1. Flow chart illustrating instructional sequence for all groups.

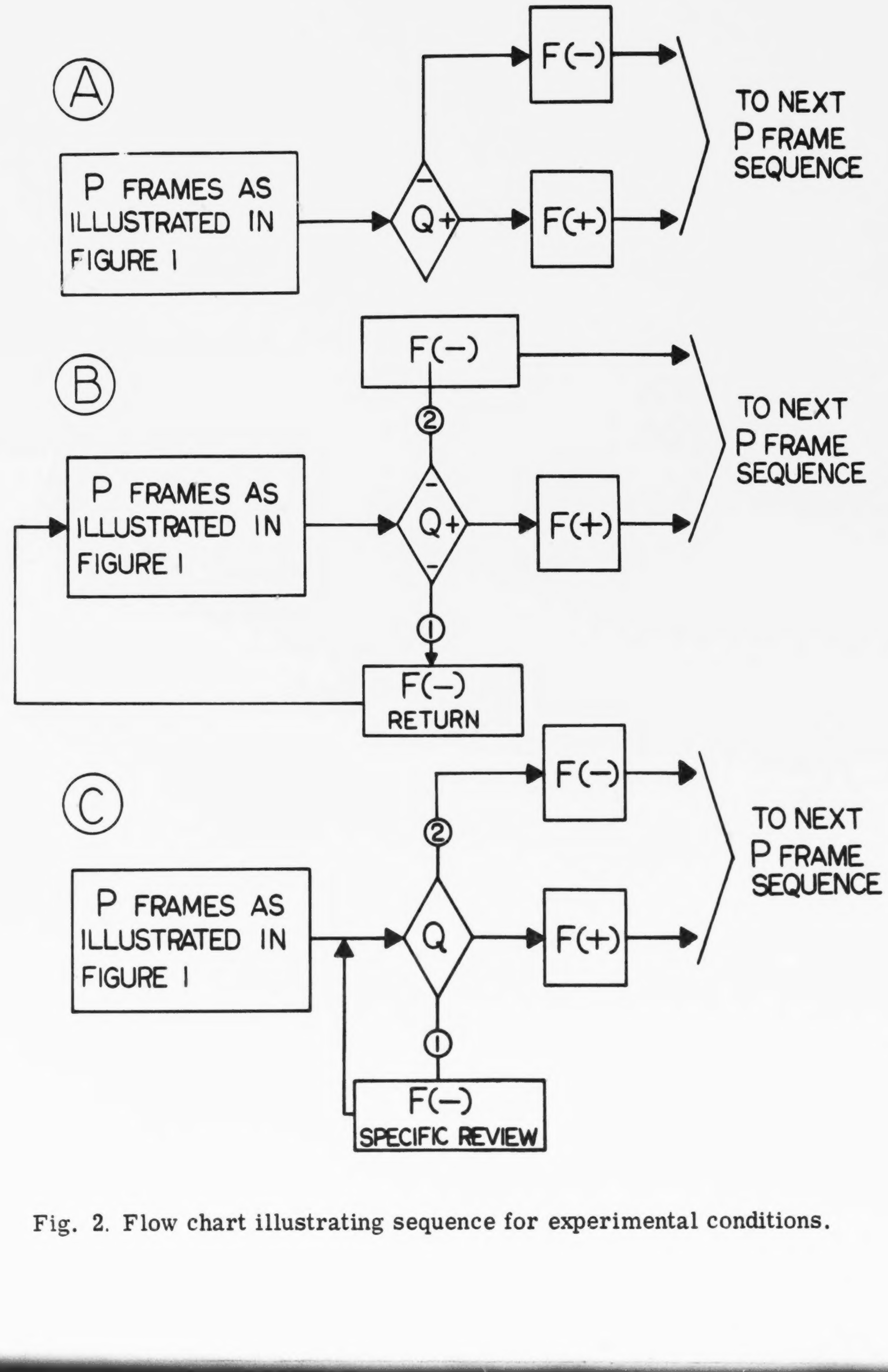
A
P FRAMES AS ILLUSTRATED IN FIGURE I
Q
+
−
F(−)
F(+)
TO NEXT P FRAME SEQUENCE
B
P FRAMES AS ILLUSTRATED IN FIGURE I
Q
+
−
−
②
①
F(−)
F(+)
F(−) RETURN
TO NEXT P FRAME SEQUENCE
C
P FRAMES AS ILLUSTRATED IN FIGURE I
Q
②
①
F(−)
F(+)
F(−) SPECIFIC REVIEW
TO NEXT P FRAME SEQUENCE

Fig. 2. Flow chart illustrating sequence for experimental conditions.

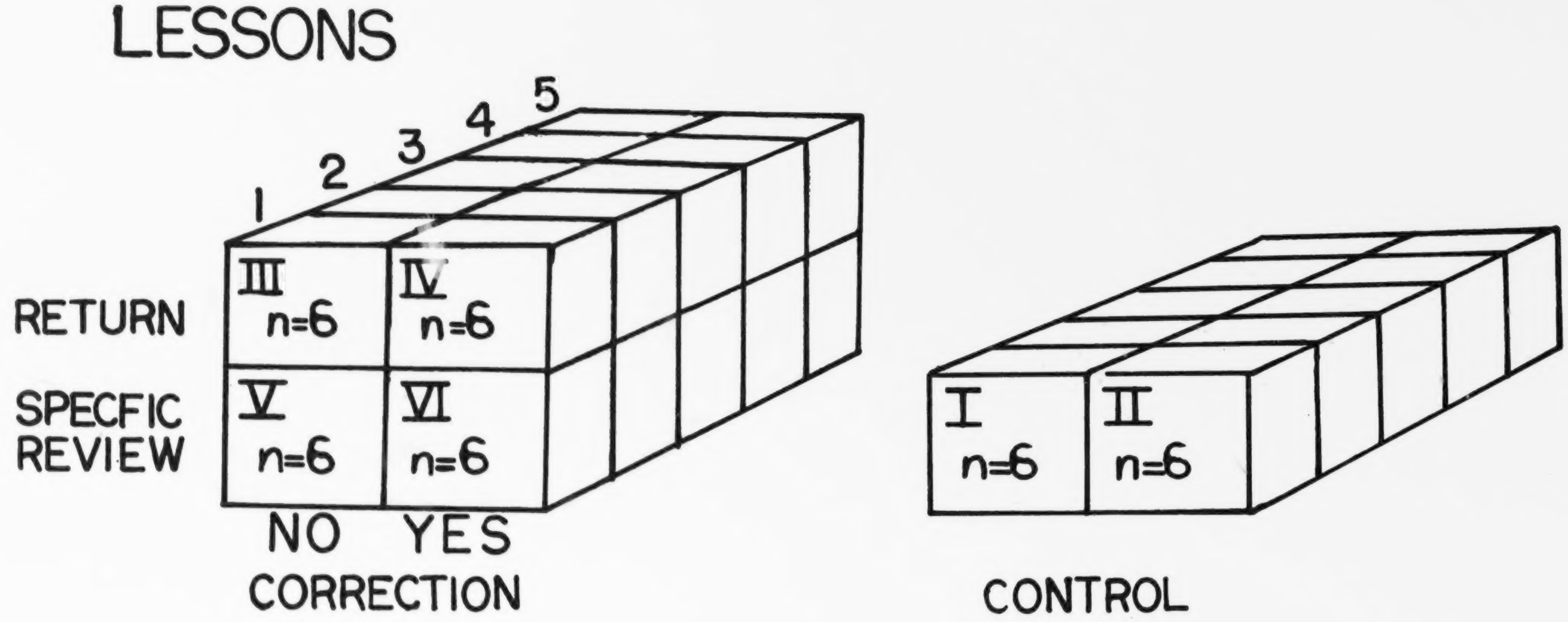
LESSONS
1
2
3
4
5
RETURN
SPECFIC REVIEW
III n=6
IV n=6
V n=6
VI n=6
NO
YES
CORRECTION
I n=6
II n=6
CONTROL

Fig. 3. Experimental design used to test hypothesis 3.

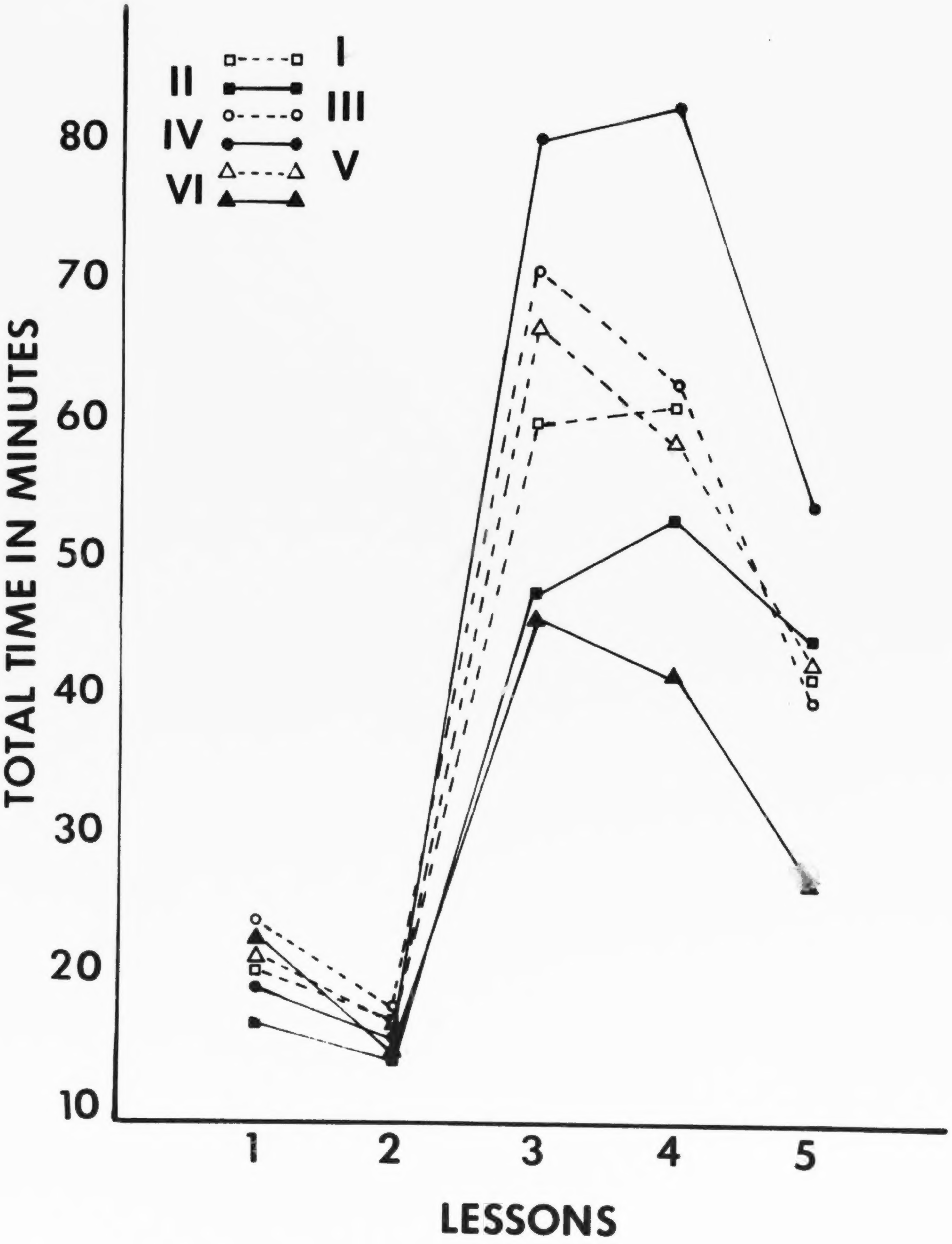

Fig. 4. Total time in minutes to complete each lesson for each experimental group.

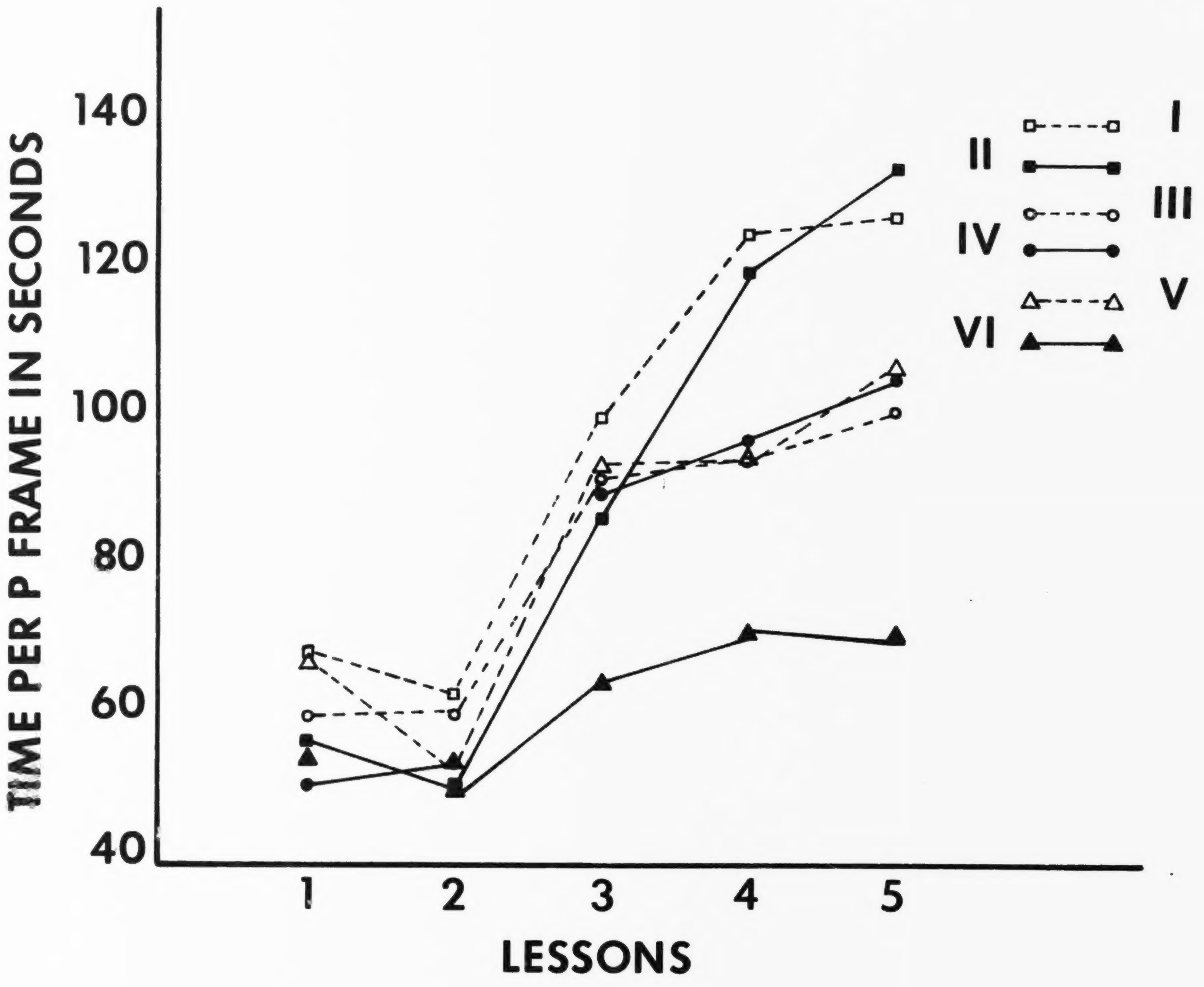

Fig. 5. Mean time spent per P frame in each lesson for each experimental group.

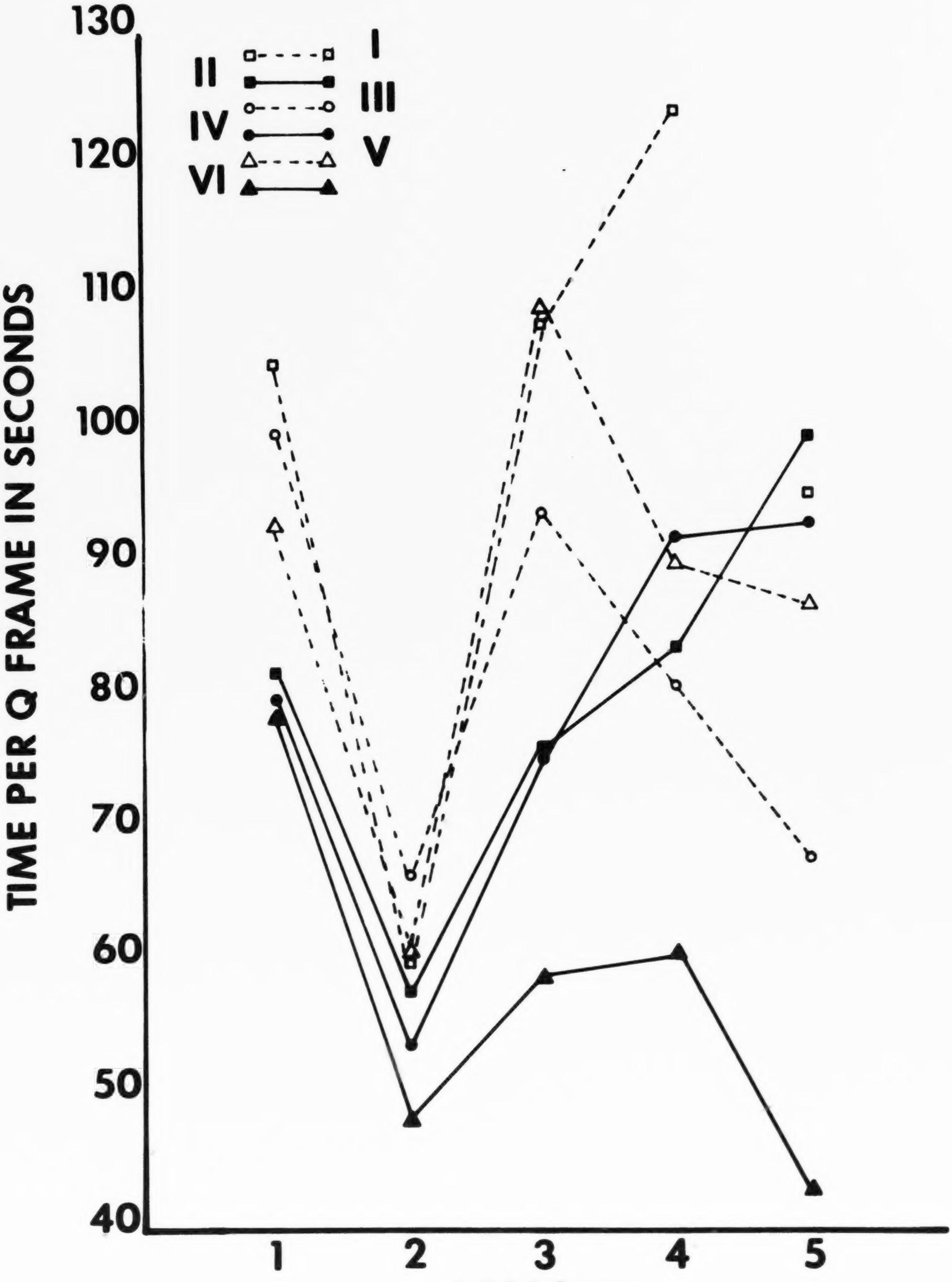

Fig. 6. Mean time spent per Q frame in each lesson for each experimental group.

EXPERIMENT 2

Departure from Proposal

It was originally proposed that experiment 2 would be a replication of experiment 1 using different age Ss and different materials. There were to have been six groups as explained above for experiment 1. These Ss were to have been second grade children and the material to be learned was basic concepts of fractions. Because of the difficulties described in the following paragraphs, this part of the research was not completed as originally proposed.

An earlier unpublished study by Genovese and Merrill (1966)[1] had shown that it was difficult for fourth grade children to learn basic fraction concepts from written programed materials. While the gain scores reached statistical significance, comparison with a control group which received an art program demonstrated that these gains were probably a result of being tested twice, rather than as a result of the programed materials. Prior to receiving the contract for this research, the development of a new fractions program was begun which greatly simplified the original material. Whereas the original program introduced fractions and went as far as principles of "reduction to lowest terms," the new program had as a terminal objective the ability to write a numerical fraction for a question such as the following:

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[1] Merrill, M. D. and Genovese, Caroline. Recall, comprehension, and application as a result of two types of programed instruction. Mimeo 1966 George Peabody College for Teachers.

> "Jane slices a banana into 7 equal pieces. She puts 6 slices on her cereal. She puts _______ of the whole banana on her cereal."

The fractions included in the test went as high as 7/8, whereas the program included fractions up to 4/5 in the hope that Ss would generalize to sixths, sevenths, and eighths.

Parts of this new program were tested with third graders using the apparatus described in studies 1 and 2. This pilot data seemed to indicate that third grade Ss could learn to solve the terminal questions after seeing the programed materials. It was found, however, that Ss needed to read the program aloud to be able to answer the questions. It was further observed that if Ss were required to point to the pictures on the frames that their responding improved.

During the pilot study described above this contract was negotiated. At that time we were sufficiently confident in our ability to improve this new program that we thought it would be ideal for use in this research. Therefore, during the negotiations, we suggested the use of this new fractions program as the material for the second experiment proposed.

The first project related to experiment 2, after receiving the contract, was to complete the empirical validation of our task analysis as described in the following section of this report. This new data tended to strengthen our confidence in the task because it was clear that second grade students did not already have the concepts which the program was designed to teach and that there should be a real opportunity to observe transfer to new situations--sixths, sevenths, and eighths--when using other fractions in instruction.

The programing procedure explored earlier was expanded and revised based on the task analysis findings. The next several months were spent writing and preparing materials both for the Merrill Individual Display Device to be used in pretesting and also on animation paper for preparation of Autotutor films.

Following the author's move to Brigham Young University, Larry Wood conducted the study described as study 1 below. In addition to the hypotheses as outlined in the report of this study, a major purpose was to pretest the programed materials for revision purposes prior to completing the films for the autotutors.[2] This testing was done using the Merrill Individual Display Device. It was found that while Ss were able to read the frames and answer questions during learning that very little gain was found on the tests. It was concluded that while the experimental control group difference on the posttest was statistically significant, it was trivial educationally. Had the program done the job, there should have been a much larger mean score difference. The hypothesized difficulty was that second grade Ss have not had sufficient experience learning from verbal materials in situations where a teacher did not provide explanation or direct attention. This reading difficulty was further verified by the Starr study which concluded that Ss learned to make correct responses but did not learn the concepts being presented.

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[2] The contract transfer from Peabody to Brigham Young University took several months so that work on preparing films was drastically curtailed during this period. Furthermore, since the transfer was not certain, it was impossible to commit ourselves to filming at this time. Subsequent problems in having films made are described in Appendix A.

Based on the Wood Study, and later verified by the Starr study it was decided that second graders would be unable to learn from an Autotutor presentation where there would be even less interaction with a teacher than was the case when the Individual Display Device was used. Several alternatives were proposed involving various aural-written combinations, but the resources available for reprograming were getting limited and it was decided to put all of our remaining energy into experiment 1, which, we felt, and subsequently found, had more likelihood for pay-off. Consequently, the fractions material replication of experiment 1 was abandoned.[3]

The following sections describe the task analysis study and the studies using the fractions program conducted by Larry Wood and Karl Starr. Both of these studies were conducted as class assignments and are therefore only partially related to this project and only partially funded by the project in that materials prepared using USOE money were used. Larry Wood was paid by the project, but his time was primarily used preparing the computer program described in Appendix B.

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[3] Subsequent filming problems depleted funds to the point where additional money would have been required to continue the fractions programing effort. Consequently, our decision to abandon this phase of the project was probably wise.

Fractional Concepts Task Analysis

A simple task like identifying the basic concepts necessary for dealing with fractions seemed like it should have been very easy. However, as we struggled with this task we found that it is not at all clear, from a psychological standpoint, just what hierarchical arrangement of concepts related to fractions represents the order used by the majority of children. A careful study was made of basic elementary arithmetic texts and of the basic method books in an attempt to derive such a sequence from these sources. Most of these books treated only a grosser level of analysis indicating that being able to identify fractional parts was prerequisite to being able to reduce fractions to lowest terms but none dealt with the finer level of analysis desired, i. e., what are the sequential steps required to learn to supply the fractional name given a situation which involves dividing a larger group into parts or dividing an object into pieces.

After considerable struggle with this problem, the list of behaviors contained in table I was derived. The procedure used to derive this list consisted of a careful analysis of the type of problem we set as our terminal objective. This type of problem is illustrated by the following example:

> "Sally has an apple. She cuts it into 3 pieces. Each piece is _____ _______ of the whole apple."

Appropriate answers include both one third and/or 1/3.

The question was asked what must the child do first in order to solve this problem. The answer to this question yielded our first behavior. This process was continued until the entire list of behaviors contained in table 1 was derived.

The first test contained in Appendix C was constructed to measure a student's ability to perform each of these behaviors. This test was constructed on a ladder principle where a set of items measured each of the behaviors in turn. In this way it was felt that it could be determined just how far into the hierarchy a given student had progressed and also if the hierarchy did, indeed, represent the order in which the student acquired ability to name fractional parts of whole objects or sets of objects. Each part of the test contained three items for a total of 24 items. Each part contained items using groups of objects and items containing parts of a whole object.

This test was administered individually to five students. The students were encouraged to talk to the experimenter while he worked the problems. The most common error made by three of the five children was to circle the answer containing the number of items or representing the numeral that was first encountered in the problem. Of the students tested, one was able to complete the test with only two errors. The others all seemed to make errors. One fact become very apparent from this pretesting. While the students could be led to solve the problems by taking one step at a time, they did not evidence "real understanding." It was as if they learned to apply a set of rules in a rather rote way but there was little or no transfer to a problem which was worded differently. Consequently, it was felt that while the steps for solving a particular kind of problem had been correctly identified, these did not necessarily represent the behaviors necessary for gaining the understanding required to be able to name any fractional part. As a result, the task analysis went back to the drawing board.

The second attempt to derive a hierarchical list of behaviors that represent the learning processes of children when learning fractions yielded, after considerable struggle with many other ideas, the simple hierarchy in table 2. The major shift from the former analysis is in the direction of being specific to particular fractions. It finally occurred to the author and his associates that children don't learn a general ability called "ability to name fractional parts," but rather they learn a set of very specific abilities, such as the ability to recognize an instance of "one half" or a little later, "one third." Finally, later, they learn non unit fractions such as "two thirds," etc. It is only after considerable learning of specific fraction concepts that the student is able to generalize and apply the rules for naming any fraction specified in table 1.

When this realization finally occurred to the experimenters, it was hypothesized that the first fraction concept learned by elementary students is the concept one half. Next, the words for unit fractional parts, such as one third, one fourth, etc. are learned. Next, they learn non unit fractional concepts, such as two thirds, three fourths, etc. Only after they have mastered verbal names for fractional situations are they able to use number symbols to express fractions, e.g. 1/2, 1/3, 2/3, etc. This hierarchical relationship is illustrated in table 2.

The test contained in Appendix D was devised to measure each of these abilities. It consisted of three parts, the first designed to measure level A, the second level B, and the third level C. Items were selected that represented parts of whole things, e. g. half an apple and others that represented part of a collection of things, e. g. one out of three balls. Unlike the test in Appendix C, this new test did not use a ladder form of construction but had test items from all three parts and both types randomly distributed throughout the test. The fractions included were 1/2, 1/3, 1/4, 2/3, 2/4, 3/4, and a random selection from sevenths and eighths.

This test was administered to 48 second grade S̲s, 60 third grade S̲s and 60 fourth grade S̲s in two different elementary schools in Murphreesburo, Tennessee. The tests were administered during May 1966 sothat each group of S̲s were almost ready for the next class, i. e., second grade S̲s would be third grade S̲s in the fall, etc.

The predicted outcome is illustrated in Figure 1 and the actual outcome is illustrated in figures 2 - 4. As can be observed, for the most part the predictions were verified. When Ss understand some, but not all, of the fundamental concepts of fractions (see especially grade three, figure 3), they understand the concept one half first, then unit fractions, and then non unit fractions. It also appears that mastery of non unit fractions and numerical representation is learned at approximately the same time.

Items 12, 16, 17, 20, 23, and 26 were eliminated from the analysis because two answers were possible, one half or 1/2 and the intended answer 2/4, 4/8, etc. It is impossible to separate Ss who knew 2/4 but reduced to 1/2 from those who merely knew 1/2.

Table 1

Behavioral sequence necessary to solve problems requiring the student to supply the numerical and verbal name of a fractional part of a whole object or group of objects.

I. Identify the set under consideration.

II. Identify the number of elements in the entire set.

III. Identify the subset.

IV. Identify the number of elements in the subset.

V. Write the numeral indicating the number of elements in the entire set under the line.

VI. Write the numeral indicating the number of elements in the subset over the line.

VII. Say the number of elements in the subset as a numeral.

VIII. Say the number of elements in the entire set as an ordinal.

Table 2

Hypothesized Hierarchy of Fundamental Concepts of Fractions

Level C	The student will be able to write non unit fractional parts in numerals, e.g., 2/3, 3/4, 7/8, etc.	NON UNIT NUMBER-NAMER IN NUMERALS
Level B	The student will be able to write how many parts, i.e., the numberator, for non unit fractions, e.g., two thirds, three fourths, etc.	NON UNIT NUMBER-NAMER
Level A_2	The student will be able to write the appropriate word for one piece or one part other than one half, e.g., one third, one fourth, etc.	UNIT NAMER
Level A_1	The student will be able to write the appropriate word for one piece or part when this is one half.	ONE HALF

It appears that the logical hierarchical analysis in table 2 is fairly representative. The experimental program was revised to follow this hierarchical structure.

FRACTIONAL CONCEPTS TASK ANALYSIS FIGURES

Fig. 1 Fraction Test - Item frequency distribution hypothesized relationships.

Fig. 2 Fraction Test - Item frequency distribution Second Grade N=48.

Fig. 3 Fraction Test - Item frequency distribution Third Grade N=60.

Fig. 4 Fraction Test - Item frequency distribution Fourth Grade N=60.

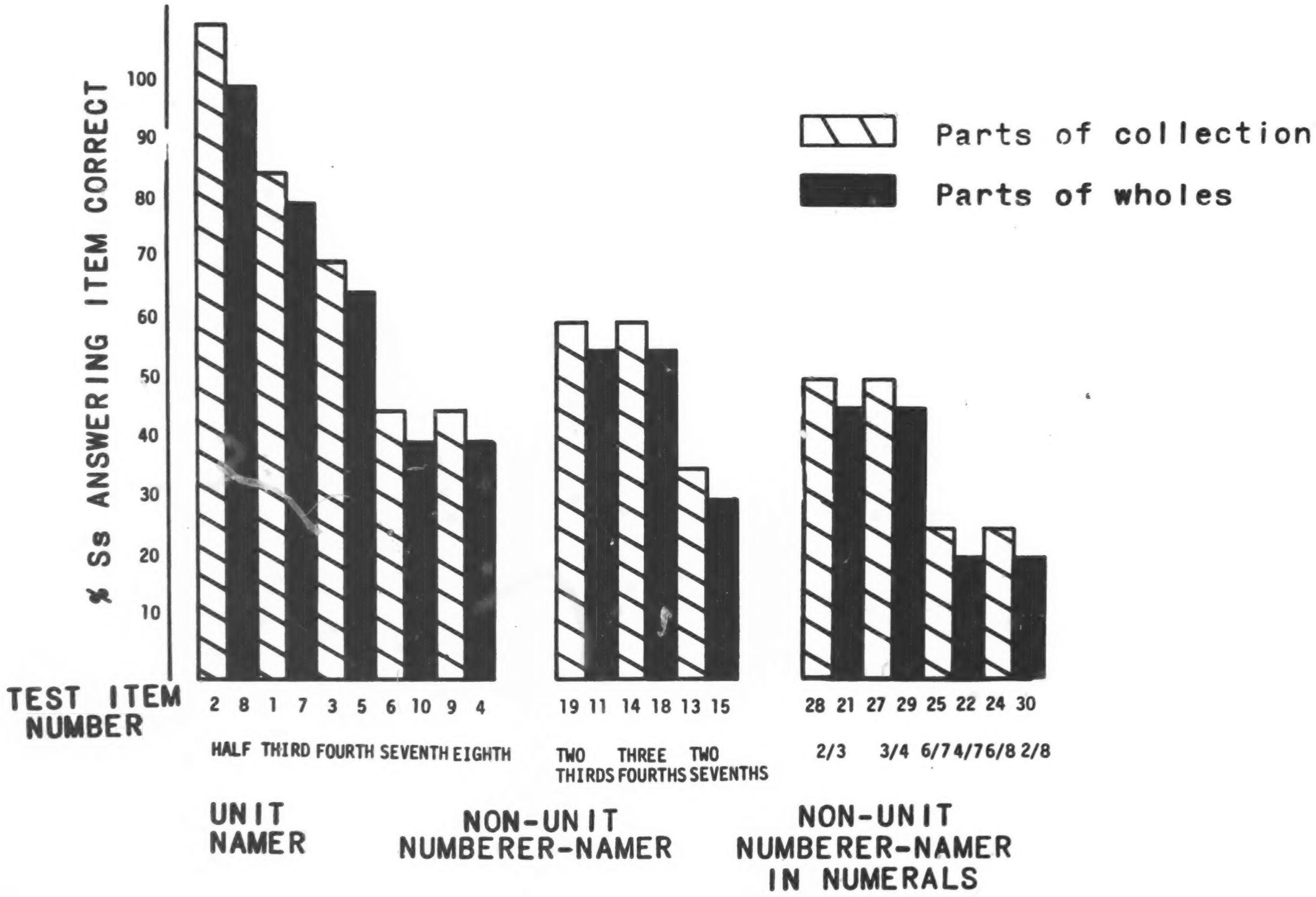


Fig. 1 Fraction Test
Item frequency distribution hypothesized relationships

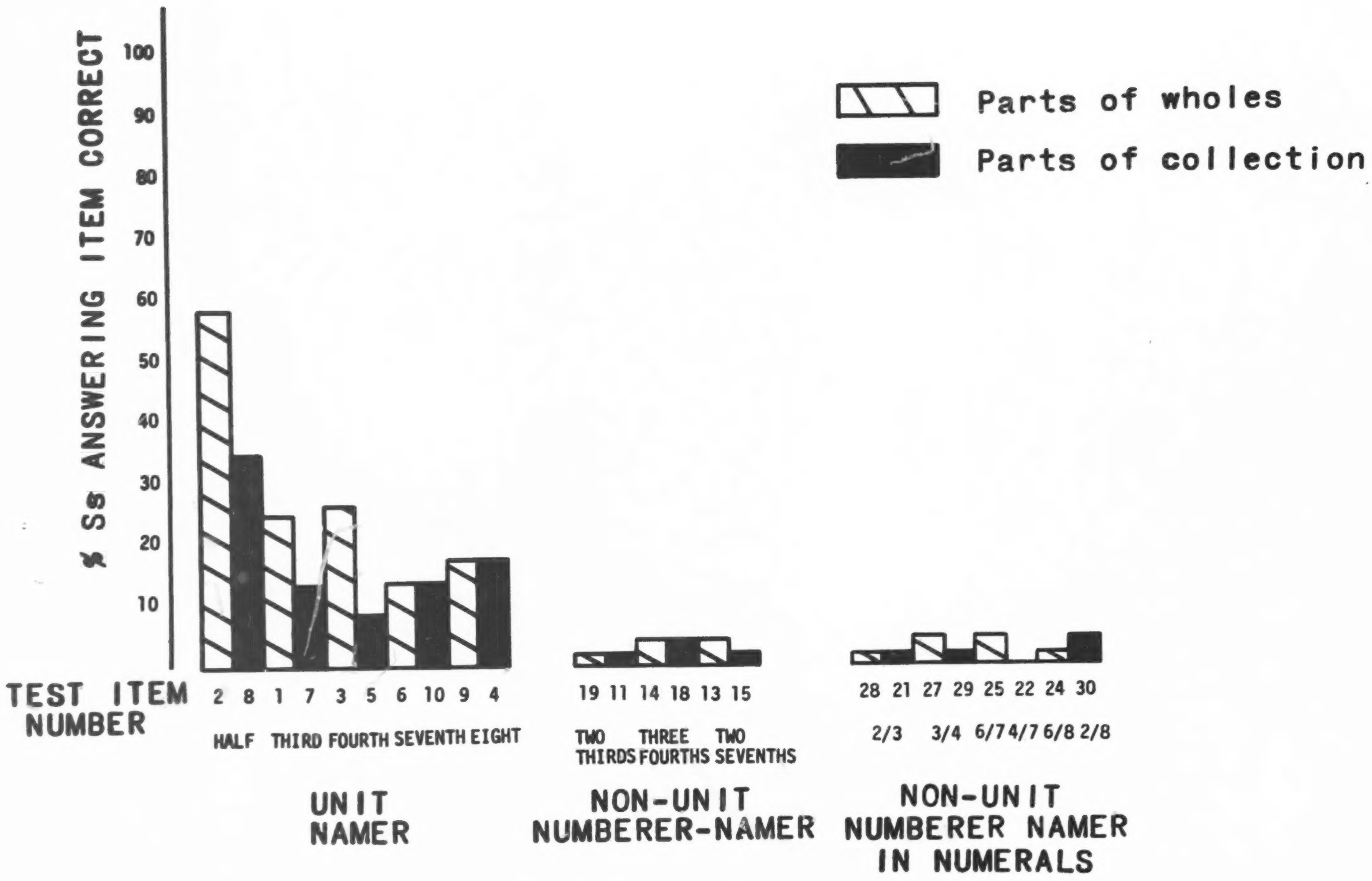


Fig. 2 Fraction Test
Item frequency distribution Second Grade N=48

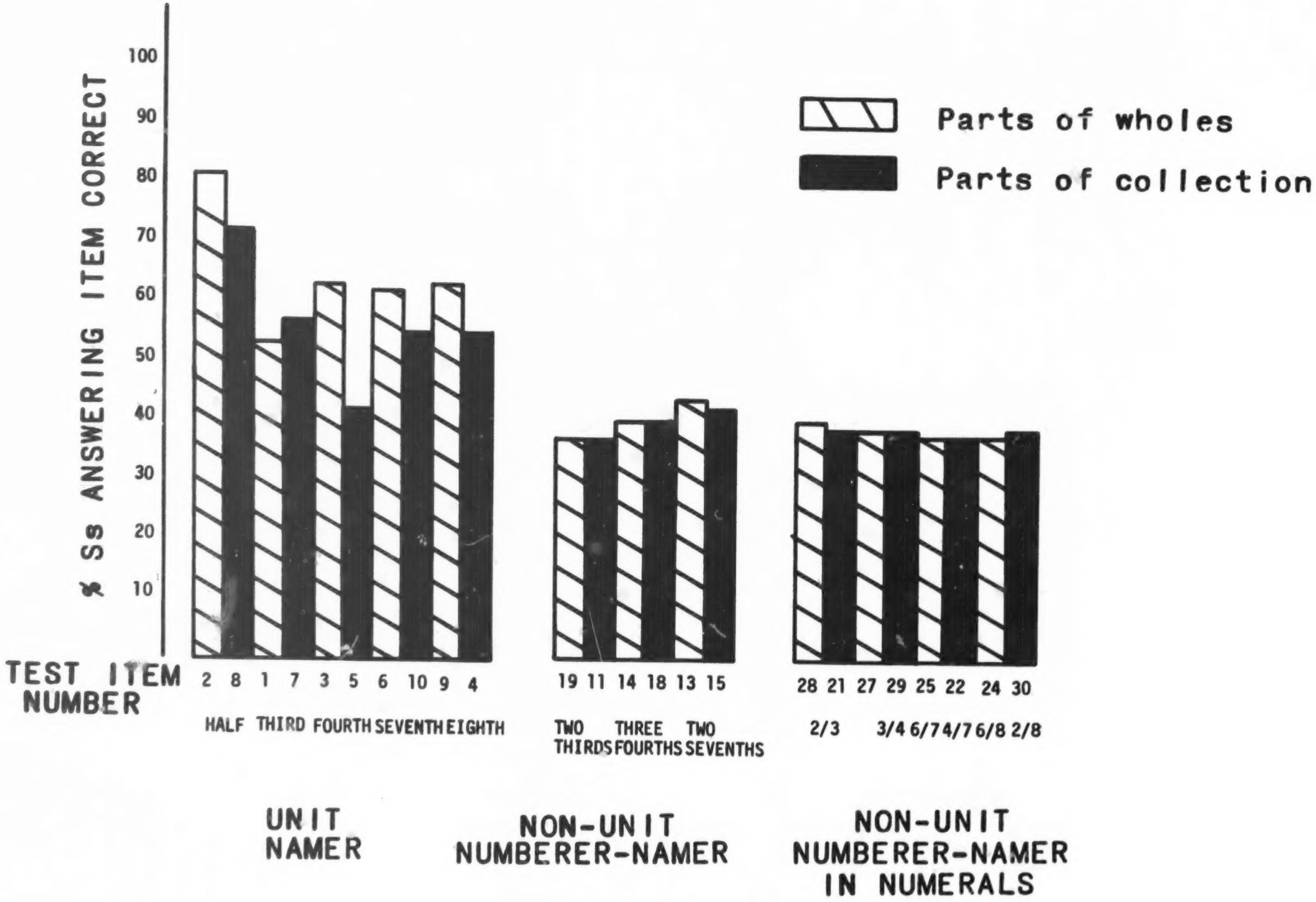
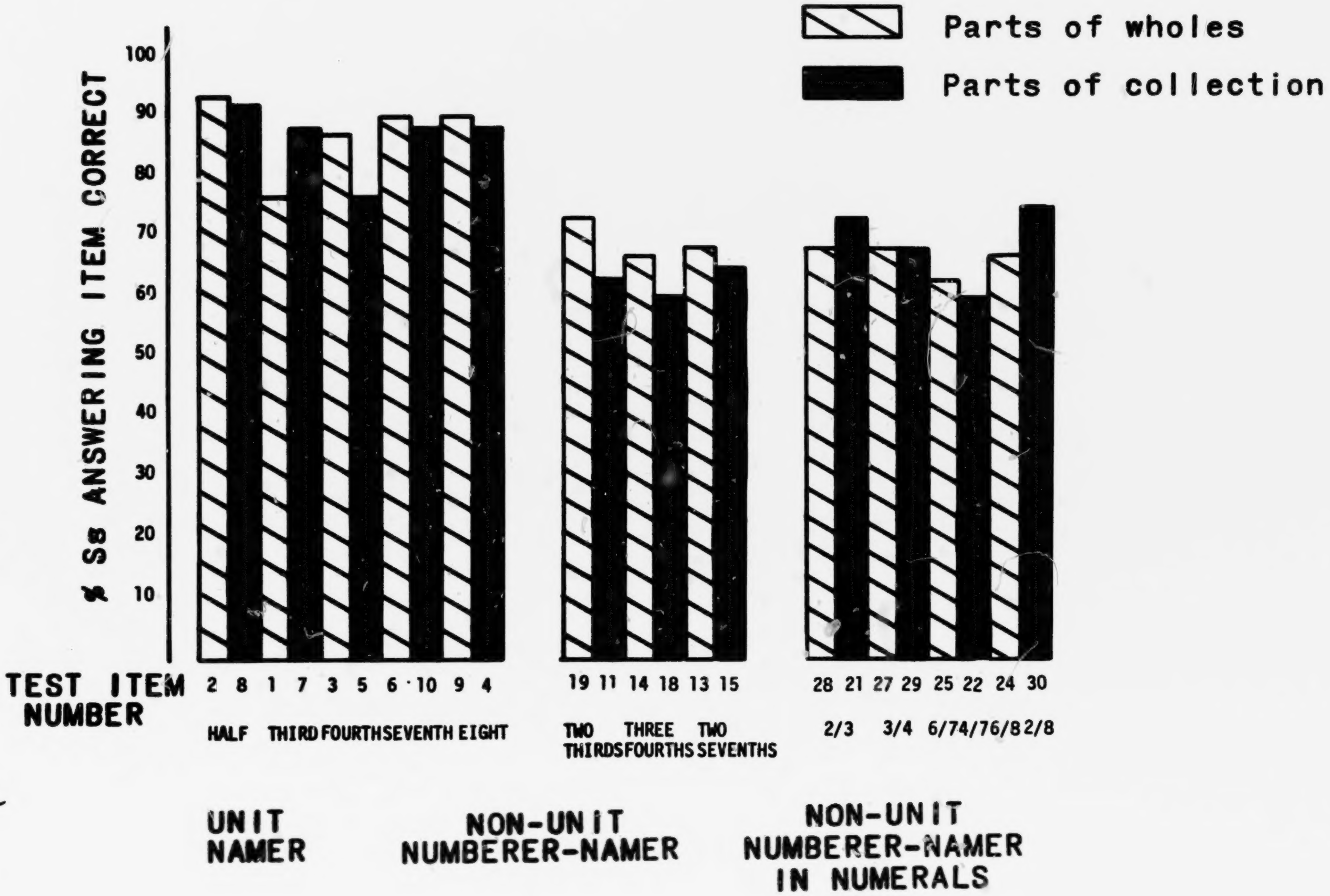


Fig. 3 Fraction Test
Item frequency distribution Third Grade N=60



2

Fig. 4 Fraction Test
Item frequency distribution Fourth Grade N=60

Introduction to Studies 1 and 2

Following the author's move from George Peabody College all funds awarded as part of this contract were unavailable while negotiations for the transfer of this contract to Brigham Young University were under way. This period of negotiation lasted for a period of several months with the final transfer of the contract being finalized in February 1967. During this period of time work on masters for filming and completing preparations for data collection were necessarily suspended. The new version of the fraction program had been previously written during the summer of 1966 and a girl was acquired using BYU funds to prepare this material for use on the author's Individual Display Device. A student of the author needed a project for a class requirement and requested permission to use the fraction program which was under preparation. The author felt this was an excellent opportunity to pretest the program and to incorporate any changes into a filmed version prior to the expense of filming this material.

The hypotheses of the Wood Study are not exactly those suggested by the proposal for this contract but, as can be observed from the following report, are closely related to the general theme, i.e., feedback conditions in conceptual school learning tasks. While this research was only partially funded by this contract and does not collect data for which the contract was awarded, it does represent a crucial link in the attempt to fulfill this research obligation and is therefore reported here.

The second study conducted by Karl Starr was completed after the contract had been transfered. It does not represent any additional funds from this contract but was seen as an additional check on the materials after the decision to abandon this portion of the proposed research. The previously observed reading difficulty was again observed and further confirmed the necessity to devise some other display device for presenting this material to elementary students at the second and third grade levels. Because this study was conducted with materials prepared for this contract a full description is included in this report.

Various Combinations of Right-Wrong Knowledge of Results on Conceptual Learning[1]

Larry E. Wood and M. David Merrill

Brigham Young University

In general it has been shown that feedback or knowledge of results facilitates learning and improves performance in a variety of psychomotor tasks (Bilodeau & Bilodeau, 1961) and paired-associate learning tasks (Hawker, 1964). Skinner (1958) assumes that the same results hold true for conceptual learning by means of programmed instruction. Some researchers have found evidence to support Skinner's assumption (Kaess & Zeaman, 1960; Krumboltz & Weisman, 1962) while others have arrived at conflicting conclusions (Moore & Smith, 1964; Rozenstack, Moore, & Smith, 1965).

The contradictory findings of effectiveness of feedback in the previous studies may be a result of the function feedback serves. It is generally assumed that feedback provides reinforcement for correct responses. Anderson (1967) suggests that knowledge of results in conceptual learning may serve not as reinforcement but as corrective feedback, that is, instead of strengthening correct responses, knowledge of results may serve to correct incorrect responses.

A study by Fergusen and Buss (1959) seems to indicate that in conceptual learning verbal "right" and "wrong" feedback serves a corrective function. They found that Ss who received a "right" for correct responses and a "wrong" for incorrect responses (R-W) did not differ significantly from a group who received no feedback from E for correct responses but a "wrong" for incorrect responses (N-W). However, both of these groups performed the learning task significantly better than a third group which was given a "right" for correct responses but no feedback for incorrect responses (R-N).

The purpose of the present study was to replicate and extend the findings of Fergusen and Buss (1959). The learning task used by them was one involving concept formation where Ss were required to identify which of several previously learned concepts was relevant. The task was presented in a way that correct identification could not have been learned had Ss not been given feedback. The learning task used in the present study involved concept acquisition where Ss were required to learn a new concept. The task was presented in a way that the correct response was possible even if E did not give S feedback.

Based on the results of Fergusen & Buss (1959) it is hypothesized that:

1. Ss receiving R-W and N-W feedback will perform better (take fewer trials and less time to learn a task, and take less time and make more correct responses on a test) than Ss receiving R-N feedback.
2. Ss receiving feedback will perform better than those who receive no feedback.

Method

Subjects

Thirty-five second-grade students from the Wasatch Elementary School in Provo, Utah, were used as *Ss*. Because of the written presentation used, it was necessary to select students who could read. The *Ss* who were used represented the best readers as judged by teacher ratings from among the sixty-seven second-grade students at the school.

Apparatus

The apparatus[2] consisted of two control panels located so that *S* and *E* sat opposite and facing each other with a partition between them. The partition prevented *S* from being distracted by *E*'s collecting data from the machine during the experiment.

On *S*'s control panel was located a window seven inches wide by nine inches long under which a program card could be inserted. On the right side of the control panel were eight toggle switches. By each was a letter which corresponded to multiple-choice answers found on the program frames (cards). Just above the toggle switches were located two feedback lights, a green one labeled "right" and a red one labeled "wrong." At the bottom of the window on *S*'s panel were nine concealed micro-switches which, when depressed, connected each response switch to one of the feedback lights. The program cards used for instruction were made of white cardboard eight inches wide by fourteen inches long and were notched according to a code so that when they were inserted, the necessary micro-switches were depressed to connect the correct response switch to the green feedback light and the remaining response switches to the red one.

E's control panel had eight toggle switches connected to those on S's panel. By each switch on E's pnael was a small light which indicated the switch thrown by S when a response was made. E's control panel was equipped with two switches connected to the feedback lights on S's panel. The switches enabled E to prevent either or both of the feedback lights from coming on when S responded. A Standard electric stop clock accurate to the nearest .5 seconds was located on the left side of E's panel, and on the right side was a clipboard to which data sheets were attached.

When a program card was inserted by E, the clock started running and continued until a response was made. When S responded, the clock stopped and S received immediate feedback indicated by the red or green light. E recorded the letter and latency of the response; and after resetting the clock, E then threw the appropriate switch on his panel which reset S's response switch and turned off the feedback light so another response could be made. E then removed the program card and inserted the next one.

Materials

The learning task used was designed to teach the concepts of the unit fractions one-half, one-third, and one-fourth and was presented in the form of programmed instruction. Each concept was presented in a unit consisting of four program frames followed by a frame containing a criterion question about the concept (see Fig. 1).

Insert Figure 1 about here

After the presentation of the concepts S was given a test consisting of twelve questions, four on each concept. Three of the questions required direct recall from S while the remaining eight were designed to measure transfer. The alternative incorrect choices used as distracters for the questions were chosen from a list of responses given on a free response test which was previously administered to second-grade students who had not received formal instruction in the fraction concepts.

Procedure

The Ss were instructed in the use of the teaching machine prior to beginning the fractions program with frames containing non-relevant material. The Ss were instructed to read each program frame as it was inserted, choose the correct response, and throw the appropriate switch when finished. Each S received repeated presentations of the frames for each fraction concept until either a correct response was made to the criterion question or a maximum of five trials were completed. One trial consisted of a presentation of the five frames for a given concept. The test questions were presented only once and no feedback was given to the responses on the test to any group.

The thirty-five Ss were randomly divided into five groups. Group I (R-W) received feedback to correct (green light) and incorrect (red light) responses on the program and criterion frames. Group II (N-W) received feedback on their incorrect responses only. Group III (R-N) received feedback on their correct responses only. Group IV (N-N) received no feedback to any of their responses. Group V (control) received only the test questions which provided a basis from which to determine amount of learning accomplished by Groups I, II, III, and IV who received the program plus the test.

Design

The design used was a two by two factorial design with an additional control group as illustrated in Fig. 2. The experimental groups were compared to the control group by the use of an orthogonal comparison. Table 1 indicates the weights used for this comparison.

Insert Figure 2 and Table 1 about here

Results

In testing the hypotheses, four variables were used to measure learning of the task: total time for the program, total number of trials to criterion, total time on the test, and number of correct responses on the test. The means and standard deviations for these variables for each group are reported in Table 2.

Insert Table 2 about here

The first hypothesis stated that Ss receiving R-W feedback and N-W feedback would perform significantly better than those receiving R-N feedback. In order to test this hypothesis, Groups I & II were compared with Groups III & IV by two-way analyses of variance for each of the four variables to determine the main effect of "wrong" feedback. The differences are not significant. The first hypothesis was not supported.

The second hypothesis was that all Ss receiving any feedback would show more learning than those who received no feedback. The interactions of the two-way analyses of variance (Groups I & IV with Groups II & III) for each of the four variables showed that the differences were not significant. The second hypothesis also was not supported.

The means of the test scores of the four experimental groups were combined and compared to the mean of the control group using an orthogonal comparison. The results of this comparison showed that the difference was significant ($F=4.63$, df 1/34, $p<.05$).

Discussion

In order to confirm the notion that feedback serves a corrective function rather than a reinforcement function in learning a concept acquisition task, it was necessary to support hypothesis 1 which would show that giving S "wrong" feedback for incorrect responses facilitates performance more than giving S "right" feedback for correct responses. To support hypothesis 1, it would be necessary to confirm hypothesis 2 which would demonstrate that any kind of knowledge of results improves learning more than no knowledge of results.

Since neither hypothesis was supported, it is evident that in the present study, feedback served neither a corrective nor a reinforcement function. In fact, knowledge of results did not facilitate learning of the task. These results agree with the findings of Moore & Smith (1964) and Rozenstack et al. (1965) in studies using college students and programmed instruction.

There are some factors which might account for the results of the present study being different than those of Fergusen & Buss (1959). First of all, perhaps there is a difference in the necessary conditions for learning between tasks involving concept formation and concept acquisition and/or between tasks which require feedback for learning and those which do not. It may also be possible that a "right" or "wrong" as indicated by a green or red light does have the same effect as a verbalized "right" or "wrong," especially on children.

Before either of the preceding conclusions can be accepted as valid, it is necessary to examine the results a little more closely. Although there was a significant difference in mean test scores between the combined experimental groups and the control group, this difference was only 1.5 correct responses. Also, there were no differences in the total time on the test. Hence, it seems more reasonable to conclude that the hypotheses were not adequately tested in this study since there was not a significant amount of learning in any of the groups.

Probably the main cause for the lack of learning was reading difficulty. Most second-grade students have not developed reading skills to a very great extent; and for the most part, they concentrate on one word at a time rather than phrases or complete sentences. A second, related factor is that most instruction at the second-grade level is done with combinations of verbal and visual presentations of material with numerous repetitions. Second-grade students have had very little, if any, experience in learning concepts from reading only and without prompting from a human instructor. Further research in this area is obviously necessary in order to resolve these questions.

Summary

Thirty-five Ss were randomly assigned to five treatment conditions. The independent variables investigated were feedback for correct and incorrect responses, feedback for correct responses only, feedback for incorrect responses only, and no feedback for either of the responses.

The results indicated that knowledge of results did not facilitate learning of the concept acquisition task. However, the results were inconclusive because none of the experimental groups showed a significant amount of learning.

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Footnotes

1. This project was supported by funds provided by Brigham Young University and by the U. S. Office of Education Small Contract No. OEC 4-7-078134-1660.

2. This apparatus was designed and constructed by M. David Merrill.

Table 1

Weights Used in Making

Orthogonal Comparisons

	Comparisons	Groups				
		1	2	3	4	5
2 x 2 factorial	right	+1	+1	-1	-1	0
	wrong	+1	-1	+1	-1	0
	right x wrong	+1	-1	-1	+1	0
	experimental vs. control	+1	+1	+1	+1	-4

Table 2

Means and Standard Deviations of the Four

Variables Used to Measure Learning

Groups	Trials		Test scores		Program time (minutes)		Test time (minutes)	
	M	sd	M	sd	M	sd	M	sd
(R-W) 1	7.3	3.6	2.7	1.4	23.9	11.3	9.3	.3
(N-W) 2	5.4	2.8	3.7	1.4	17.6	8.3	8.2	1.5
(R-N) 3	8.0	4.4	2.0	1.6	20.7	11.3	7.6	1.5
(N-N) 4	8.3	3.3	2.7	1.8	24.7	10.0	8.0	1.2
(Control) 5	---	---	1.4	1.0	---	---	8.9	1.5

FIGURES

Fig. 1. The program sequence for the concept of one-half.

Fig. 2. The experimental design.

FIGURE 1
The program sequence for the concept of one-half

Frame 1

The
apple has
been cut
in half.
This means
it has been cut into
___?___ equal pieces.

four D
three C
one B
two A

Frame 2

One piece is
one half of
the whole
apple. This
means one
of the two equal pieces
is ___?___ of the
whole apple.

one piece D
one half C
two halfs B
one part A

Frame 3

A cookie is cut in half.
This means the cookie
has been cut into ___?___
equal pieces.

four D
one C
two B
three A

Frame 4

One piece is one half
of the whole cookie.
This means one of the
two equal pieces is
___?___ of the whole
cookie.

two halfs D
one part C
one half B
one piece A

Criterion Frame

Mother baked a pie.
She cut the pie into
two equal pieces.
Each piece is ___?___
of the whole pie.

two halfs D
one half C
two parts B
one part A

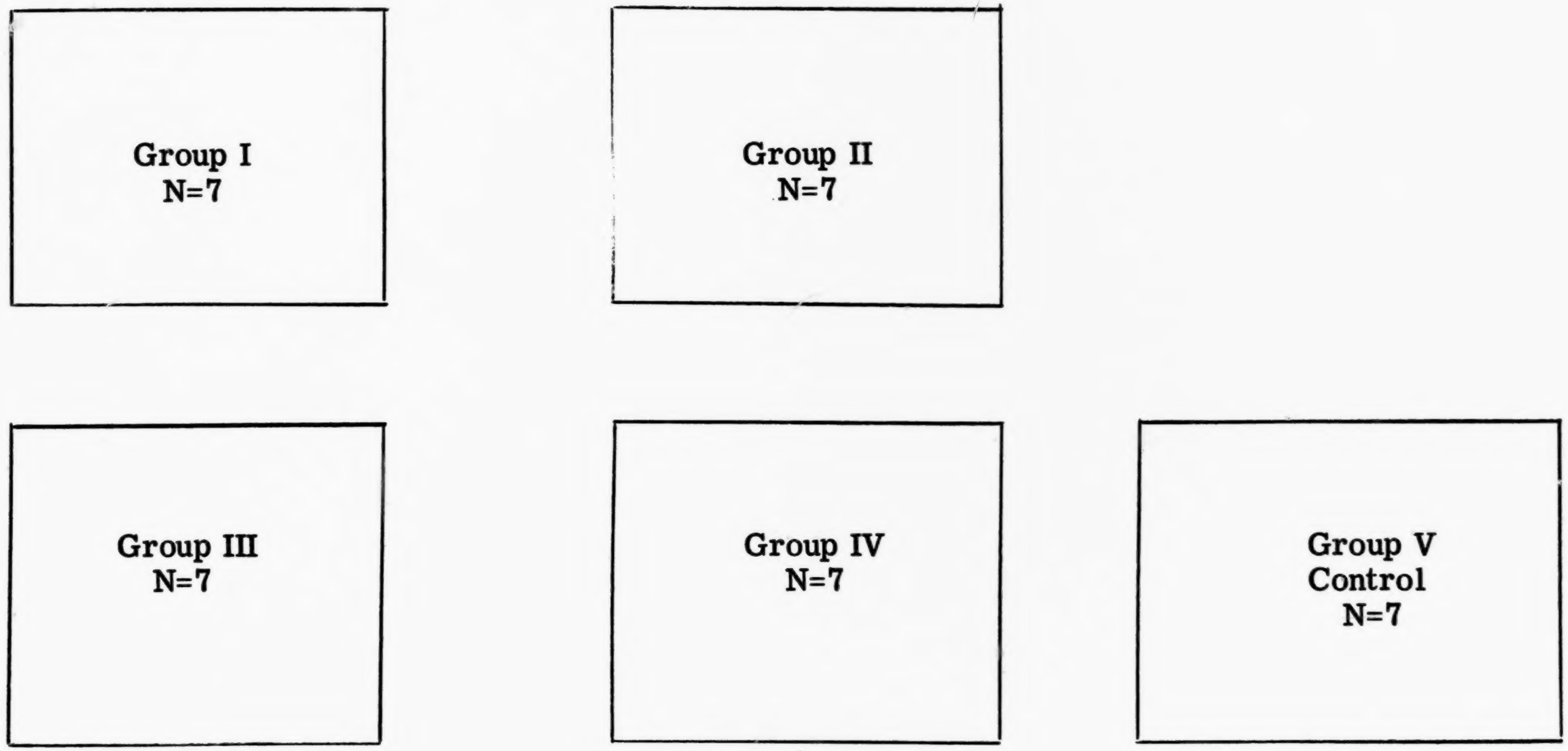
Group I
N=7
Group II
N=7
Group III
N=7
Group IV
N=7
Group V
Control
N=7

FIGURE 2
The experimental design

Amount of Negative Knowledge of Results in Naming Fractional Amounts

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Kaess and Zeaman (1960) presented beginning psychology students a multiple choice test repeated five times in which the number of response alternatives on the first trial varied for different groups. On all trials students were allowed to continue responding on a Pressey punchboard (1950) until they found the correct response. Those students who had only the correct alternative and, consequently, received no negative knowledge of results on the first trial performed with fewer errors on subsequent trials than those Ss who had one or more distractors in addition to the correct alternative.

The present study was designed to replicate the findings of the Kaess and Zeaman study using a very different population of Ss (second graders, as opposed to college students); and under conditions where not only errors but latency of response could also be observed.

Based on the findings of Kaess and Zeaman (1960), it was hypothesized that: (1) Ss who are provided Knowledge of Results (K of R) on the first trial will perform better on subsequent trials than Ss who respond to the questions but receive no K of R on the first trial. (2) Ss who have no distractors on the first trial will make fewer errors on subsequent trials than Ss who have one or more distractors on the first trial. Kaess and Zeaman did not look at latency, but it seems reasonable to assume that (3) Ss who have more distractors will take longer to respond than Ss who have fewer distractors and that this time differential will probably persist on subsequent trials.

Method

Subjects

Ss were 20 second-grade pupils from the Brigham Young University Laboratory School. None of the Ss had previously received any instruction covering the content of the material used in this study.

Apparatus

The apparatus consisted of two control panels located so that S and E sat opposite and facing each other with a partition between them. The partition prevented S from being distracted by E's collecting data from the machine during the experiment.

On S's control panel was located a window seven inches wide by nine inches long under which a program card could be inserted. On the right side of the control panel were eight toggle switches by each was a letter which corresponded to multiple-choice answers found on the program frames (cards). Just above the toggle switches were located two feedback lights, a green one labeled "right" and a red one labeled "wrong." At the bottom of the window on S's panel were nine concealed micro-switches which, when depressed, connected each response switch to one of the feedback lights. The program cards used for instruction were made of white cardboard eight inches wide by fourteen inches long and were notched according to a code so that when they were inserted, the necessary micro-switches were depressed to connect the correct response switch to the green feedback light and the remaining response switches to the red one.

E's control panel had eight toggle switches connected to those on *S*'s panel. By each switch on *E*'s panel was a small light which indicated the switch thrown by *S* when a response was made. *E*'s control panel was equipped with a switch connected to the feedback lights on *S*'s panel. The switch enabled *E* to prevent the feedback lights from coming on when *S* responded. A Standard electric stop clock accurate to the nearest .5 seconds was located on the left side of *E*'s panel, and on the right side was a clip board to which data sheets were attached.

When a program card was inserted by *E*, the clock started running and continued until a response was made. When *S* responded, the clock stopped and *S* received immediate feedback indicated by the red or green light. *E* recorded the letter corresponding to the response and then proceeded as follows: (1) If the response was correct, the latency of the response was recorded from the clock and the clock was reset. *E* then threw the appropriate reset switch on his panel and inserted the next program card. *OR* (2) If the response was incorrect, *E* merely recorded the response letter and threw the reset switch allowing *S* to try again. Since the clock was not reset, the time recorded when *S* finally did find the correct response was the total time spent on that question card. For the control condition, described below, E threw the switch making the feedback lights inoperative. When S responded his response letter and latency were recorded, the appropriate reset switch was thrown, the clock reset, and a new program card inserted.

Materials

The materials presented consisted of 15 multiple choice questions which required S to recognize the correct name of fractional amounts. All of the questions which were used were similar to the following:

> "Mike had five pieces of candy. He gave two to Bill.
> He gave away ___________ of all his candy.
>
> Choose one:
> * two-fifths
> * five halves
> * one-fifth
> * one-half

The alternative incorrect choices used as distractors for the questions were chosen from a list of responses given on a free response test which was previously administered to second-grade students who had not received formal instruction in the fraction concepts. All material was printed in large black letters so that the question and its alternatives filled the 7 x 9-inch frame. No pictures or numerals were used.

Procedure

Each S was presented with three successive trials, each consisting of the same 15 multiple-choice items. Ss were randomly assigned into five experimental groups. On trial A, Group 1 received the 15 items with only the correct response displayed as a response alternative. His response consisted of flipping the switch corresponding to the letter by this alternative. Group 2 received the 15 items with only the correct response and one distractor present. Group 3 received the same items with the correct response and two distractors present, and Groups 4 and 5 received the same items with the correct response and three distractors present. Groups 1 through 4 all were allowed to continue responding until they found the correct response, while Group 5 was not given any feedback (the light didn't work) on trial A and, consequently, gave only a single response to each item. For the conditions of trial A, distractors that were to be eliminated were selected by a random procedure in order to prevent biasing of results through selective elimination of difficult or easy distractors.

All groups received the same 15 items for trials B and C, each consisting of the correct response and three distractors. On trials B and C Ss were allowed to continue responding until the correct response was found. The feedback lights operated for every group as described for groups 1 through 4 above on trial A. The sequence of the test items was determined randomly and was different for each trial. The position of the response alternatives on a given item was different for each trial and was determined by a random procedure.

Each S was selected from among his classmates by the teacher and was sent individually to the testing room. Each S was assigned randomly to one of the five treatment groups as he came to the testing room. The same instructions were given to all Ss and consisted of the following: The purpose of the study was briefly explained; instructions for operating the apparatus were given with practice on some introductory materials; then each S was told that he would be presented with some cards having only one answer, some having two answers, some having three answers, or some having four answers; and that the lights might work for him or they might not. He was told that he would receive the same material three times and that he was to try to find out the correct answer and was to try to remember it from one trial to the next. Finally, he was told that he would receive help with reading difficulties but not with the answers.

Trial A was followed immediately and without comment by trial B. A three-minute break was provided between trials B and C. The total administration time for each S was approximately 45 minutes.

Results

Figure 1 illustrates the mean number of incorrect responses for each group on each trial.

Hypothesis 1 predicted that Ss who received K of R would make fewer errors on subsequent trials than Ss who received no K of R. The Ss in groups 4 and 5 took the same tests except that on trial A Ss in group 4 received K of R, while Ss in group 5 received no feedback. A Lindquist (1953) type I design using groups 4 and 5 (Kof R vs. No K of R) as the between groups comparison and trial B vs. trial C as the within groups comparison indicated that the main effect for K of R vs. No K of R was significant ($F=4.62$, $p<.05$). The main effect for trials and the interaction were not significant.

Hypothesis 2 predicated that Ss who have several distractors on trial A will make more errors on subsequent trails than Ss who have no distractors but are given only the correct answer. An examination of Figure 1 indicates that on trials B and C, Group 1 made fewer errors than did Groups 2, 3, and 4. This difference was also tested with a Lindquist (1953) Type I analysis. The among groups effect was significant ($p < .05$). It appears from Figure 1 that the difference is between Group 1 and the other groups. The analysis was repeated for only Groups 2, 3, and 4, and was found to be non-significant ($F = .433$). Again, there was no difference between trials B and C. The interaction was significant ($p < .05$), probably as a result of Group 4's drop in errors on trial B and subsequent increase on trial C.

Figure 2 illustrates the mean number of seconds per trial for each group. As can be observed, there appear to be differences between Groups 2, 3, and the remaining groups on trials B and C.

Hypothesis 3 predicted that the more alternatives present on trial A, the more time would be required to respond on this and subsequent trials. A close examination of the figure reveals that, except for Group 1, which had only one alternative on trial A, the inverse relationship to that predicted was found; i. e., Group 2 took longest, Group 3 next, and Groups 4 and 5 were about the same as Group 1 on trials B and C. A Lindquist (1953) Type I analysis with Groups 1-5 being the among groups comparison and trials B and C being the between group comparison showed the among groups comparison to be significant (F=13.9, $p < .01$); the between trials comparison to be significant (F=42.3, $p < .01$); and the interaction of trials and groups to be significant (F=8.78, $p < .01$). The differences can be summarized as follows: On trial A, Groups 2 and 3 (with 2 and 3 response alternatives) take longest; Groups 4 and 5 are less than Groups 2 and 3 but greater than Group 1. On trial B, Group 2 (two alternatives) takes longer than Group 3, who in turn takes longer than Groups 1, 4, and 5. The significant change results from the increase in time for Group 1. On trial C, Group 2 takes longer than Groups 1, 3, 4, and 5, who are no longer significantly different from one another although Group 3's mean is slightly higher than Groups 1, 4, and 5.

Discussion

Hypotheses 1 and 2 were supported and replicate the findings of Kaess and Zeaman (1960). However, there are some important differences between the results reported in Figure 1 of this study and the results reported in Figure 2 of the Kaess and Zeaman Study. First, note that in the previous study there is a considerable improvement for Groups 3, 4, and 5 between trial 1 and trial 2. In the present study Groups 3 and 4 evidence little learning from trial to trial. Group 4, for example, makes as many errors on trial C as were made on trial A. In both studies Group 2 made more errors when introduced to the four alternative situation for the second trial, but in Kaess and Zeaman's study this group gives evidence of learning on trials 3, 4, and 5 while in the present study the error rate levels off but does not evidence any decline by trial C. This difference is best explained by the wide difference in age level. Kaess and Zeaman's college students were able to rapidly memorize the material being presented as a result of the feedback. In the present study second graders found the material difficult to learn and actually showed very little gain from trial to trial. A previous unpublished study (Wood and Merrill, 1967) found that a test only control group were able to answer only 1.5 more questions than second grade Ss who studied carefully-sequenced program materials designed to teach the behavior required by the test problems used in the present study. It was concluded by Wood and Merrill that "Second grade students have had very little, if any, experience in learning concepts from reading only, without prompting from a human instructor." The same observation applies to the present study. While there are group differences as reported above, the Ss in this study gave very little evidence of having learned any of the concepts presented by the problems being used.

Further examination of the two figures (Kaess and Zeaman, Figure 2, and Figure 1 of the present study) indicates some important similarities. While the presence of any distractors in the first trial seems to interfere with subsequent performance, it is interesting that in neither study is there positive evidence that the number of distractors has a significant effect on performance on subsequent trials. There is no apparent difference in number of incorrect responses for Groups 2, 3, and 4 of this study on trials B and C nor is there any apparent difference between Groups 2, 3, 4, and 5 on trials 2, 3, 4, or 5 of the Kaess and Zeaman study. This relationship holds whether or not the data gives evidence of improvement from trail to trial or no evidence of improvement from trial to trial.

While the number of distractors, if any are present, does not seem to effect error rate, they do seem to have an effect on the rate of responding as measured by the time used for each trial, but not in the direction predicted by hypothesis 3. If hypothesis 3 had been substantiated, Group 4 would have taken the most time, with Group 3 next, etc. Group 1 was the only Group to behave consistently with this hypothesis.

Kaess and Zeaman conclude that their study supports the assumption of Porter (1957) and Skinner (1958) that incorrect items interfere with the acquisition of correct responses. This generalization implies that this relationship holds whether the task being learned required S to understand the material being presented or merely to memorize which alternative is correct. A question not really answered by either Kaess and Zeaman or the present study is as follows: Does the student in this particular experimental situation really try to learn the meaningful relationships represented by the material or is he merely trying to remember, for a particular item, which alternative is correct? In other words, does the conceptual meaningfulness of the material presented have anything to do with the learning that results or is this merely a paired associate task of some sort where the student rotely memorizes the appropriate alternative for a particular stimulus cue?

Several findings of the current study suggest such an interpretation. First, the second graders obviously didn't understand the material being present even after completing the task. This was equally true of Group 1 as well as the other groups. The data is clear, however, that Group 1 Ss were better able to remember which alternative belonged to a particular question. It seems logical if one has to memorize which alternative is correct, in what to the learner is a relatively rote learning situation, that having to guess at several alternatives makes it difficult to remember which was the last guess, whereas, if there were only one choice, such interference is not present.

A second curious finding in the present study is the time relationships for the various groups. If, as suggested in the previous paragraph, the task is a relatively rote memorization task to the subject, then his behavior might be interpreted as follows: When he has only one distractor (as in Group 2), he makes a conscious effort to memorize the alternative and to respond correctly on the second trial. This would account for the rather long response time on subsequent trials. As the number of alternatives increase, the memory load for the student increases so that on subsequent trails he just can't remember which alternative was correct and hence relies on a haphazard flip-the-switches and find-the-answer type of strategy which requires much less time. This interpretation would be consistent with all of the time relationships. In Group 3 three alternatives is not too much of a memory load for some Ss, while for others, it is too much. Hence, Ss in Group 3 would fall somewhere between the time for Group 2 where most Ss are trying hard to respond correctly and Group 4 where most Ss are just flipping switches rather than trying to remember. Group 5, which received no feedback on trial 1, has no alternative but to resort to a switch-flipping mode of behavior making their performance comparable with Group 4.

The following studies are suggested as a way of partially resolving the questions raised above. The Kaess and Zeaman study and the present study should be replicated using nonsense materials rather than conceptual materials. It is hypothesized that the error relationships would be the same as those found by both of these studies and that the time relationships would be comparable with the present study. A second study should be conducted using conceptual materials in which the problems used required at least comprehension behavior (see Bloom, et al, 1956). Rather than merely repeating the same test several times, each trial should consist of a parallel test which tested the same concepts and principles but which used different examples in the test questions. It is hypothesized that in this situation the relationships found for these two studies would no longer hold, that the groups having several alternative responses on trial 1 may, in fact, perform better on the parallel transfer questions than the single alternative Ss.

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Footnotes

1. Karl Starr was on the faculty at Brigham Young University prior to his appointment in Samoa. This research was supported by funds supplied by Brigham Young University and by U. S. O. E. contract No. OEC 4-7-07813-1660.

2. The Individual Display Device used in this study was designed and constructed by M. David Merrill.

FIGURES

Fig. 1 Indicates the average total number of incorrect responses per trial by group.

Fig. 2 Indicates the average total amount of time required per trial by group.

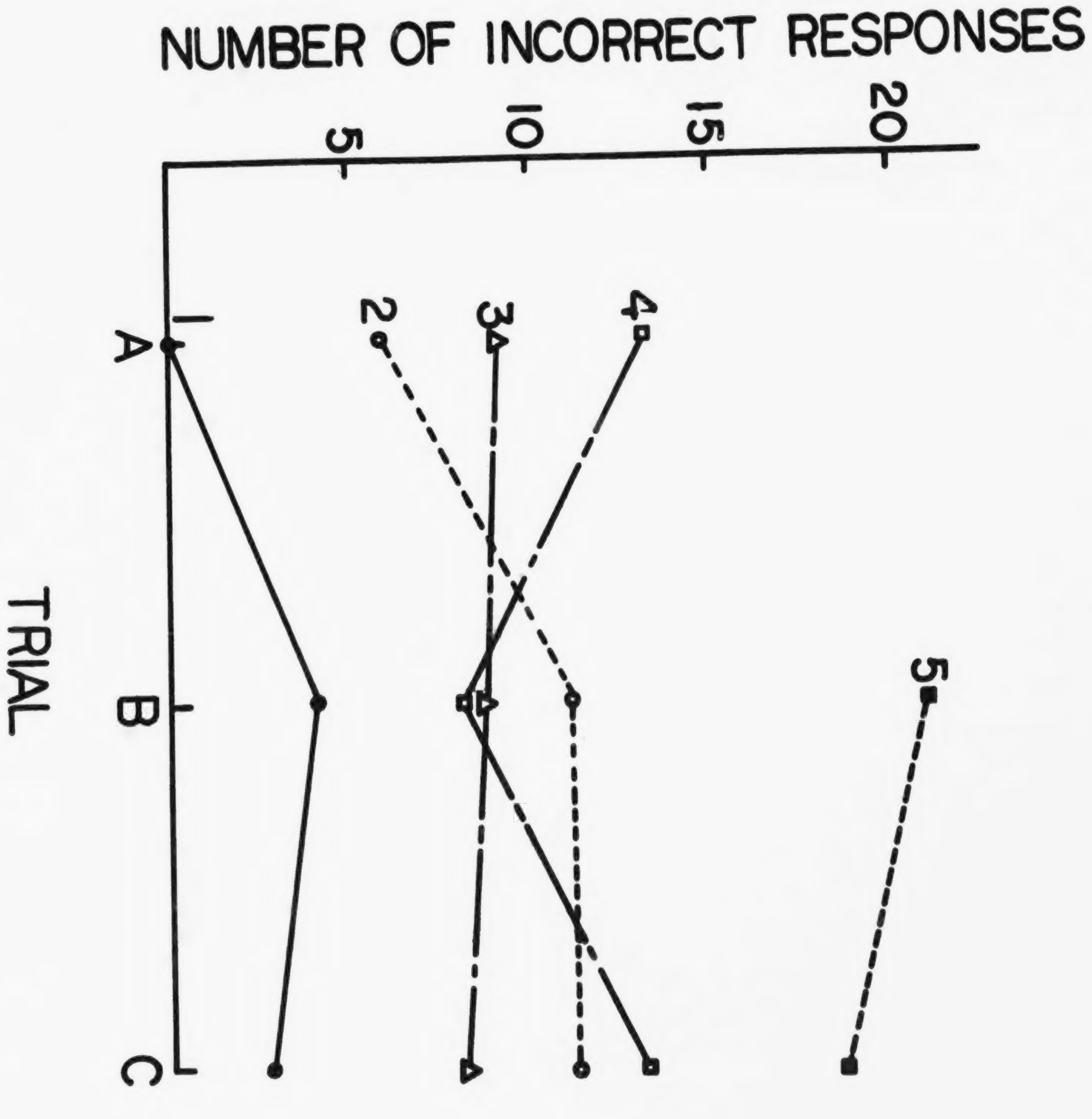

Fig. 1 Indicates the average total number of incorrect responses per trial by group.

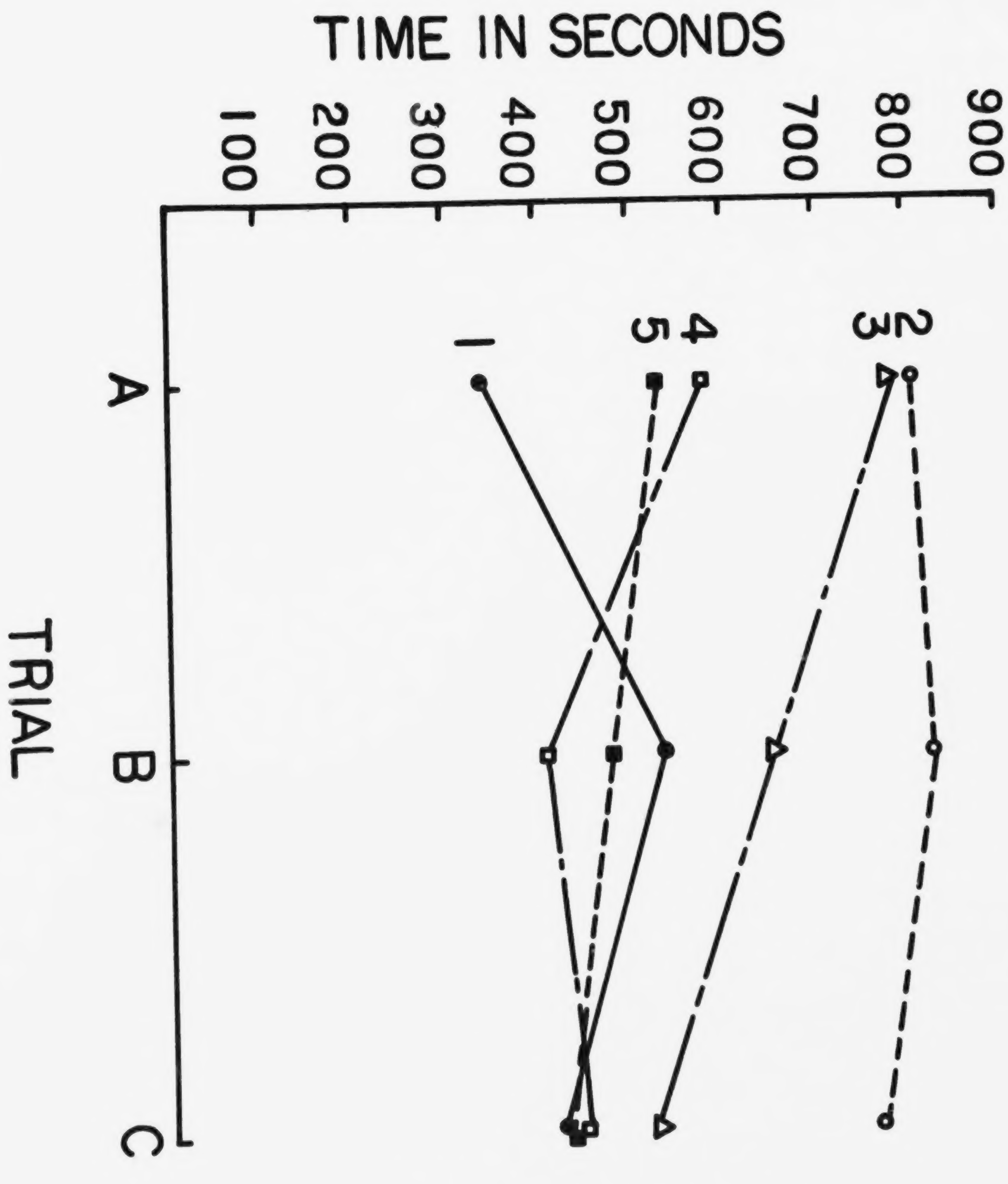

Fig. 2 Indicates the average total amount of time required per trial by group.

SUPPLEMENTARY INFORMATION

Appendix A

Filming Procedure and Problems for Autotutor Films

Autotutor operation:

In Autotutor Mark II Teaching Machines, programed materials are recorded on black and white, 35 mm, high contrast microfilm and are projected to Ss on a high contrast, rear-projection lenscreen. Ss respond to the material on the film by pushing one of ten buttons which are located to the right of the viewing screen. Depending on which button is pushed, the film moves an odd number of frames forward (1, 3, 5, . . ., 15) corresponding to buttons A - H, 19 frames backward for button I, or returns to the previous frame for button R. This procedure allows a semi-random access to the materials on the film.

Preparation of copy for filming:

The material to appear in the Autotutor program must be prepared very carefully for filming. This preparation is subject to the following restrictions which increase the difficulty of preparing films for use in this equipment. First, copy must be layed out exactly the same on each page. Failure to meet this restriction results in a program which is difficult to read because copy is chopped off by the edge of the viewing screen, or copy is positioned differently on each frame, which is very irritating to the student viewing the screen. Second, copy must be very dark and printed slightly larger than conventional typewriter size. If the copy is too light, it does not film adequately and is difficult or impossible to read on the viewing screen. Because the lenscreen is slightly smaller than standard 8 1/2 x 11 paper, there is a reduction in the size of print when it is projected. Conventional size typewriter print (even pica) is uncomfortable to read when projected on the Autotutor screen. Third, electric eyes in the Autotutor, which control restrictions in button operation, require a black coding strip to appear across the entire bottom of each frame of the film, or for some conditions, on one side or the other across the bottom of each frame. To achieve exact positioning of this coding strip, it is necessary to preprint the paper being used for filming. Fourth, editing of the materials for each frame must be very exact. Because the button pressed controls the movement of the film, it is crucial that a given frame indicate with 100% accuracy the correct button to be pushed. If a given frame indicates that the student should push button B, when in fact he should push button D, then pushing the indicated button moves the film three frames forward when it should have moved seven frames forward. It is frequently impossible for the student to know of the error and he continues to respond in an erroneous sequence, unaware of his error and thereby invalidating his data for the research being conducted. Fifth, every frame appearing in the film must be prepared on a separate copy master and the entire program must be ordered in the exact sequence to appear on the film. When a button is pressed, the film moves the required number of spaces. If by accident a frame is left out of the film, then the stopping place is not that which was desired. Like the above example, the student frequently does not know of the error in the program and continues to respond to the material on the film as if all were well. If a sequence error is contained in the program film, his data record is erroneous and lost to the experiment being conducted.

The filming restrictions described in the previous paragraph were accomplished for the research described in this report by using the following procedures:

Animation paper. Each frame was prepared on specially-coated preprinted animation paper. The surface of this paper was treated for maximum brightness and for lack of glare when being photographed. Coding strips were printed in the precise location required on the bottom of each sheet. Different sheets were used for each code. In addition, guidelines indicating the edge of the lenscreen when projected and also the suggested margin for copy was preprinted on these sheets. This paper was obtained, printed ready for the preparation of copy, from:

Haagen Printing and Offset
32 East Victoria Street
Santa Barbara, California

The size of the actual sheets was 10 by 12 1/2 inches. The sample sheet on the following page has been photo reduced to fit the format of this report.

2"

1"

Y

4 3 2 1

Typewriter. The only typewriter that does an adequate job for preparing copy for filming is IBM's Executive Model D equipped with carbon ribbon and Bold Face #1 type style. The print is larger than convential pica type and the carbon ribbon makes a very black image that photographs very well. The Executive spacing, while not a necessity, makes the films look as though they were prepared from printed copy rather than from typewritten copy.

Because we did not have access to this particular machine for much of the preparation of the films used in the current project the majority of the Xenograde films used were prepared using an IBM Selectric typewriter with pica size and delegate style of type. This gave an image with a heavy line but not as large as desirable. The lightness of the image was overcome to some extent by having the films printed darker than normal. This process caused some fogging of the film but produced a dark image that was easier to read.

Illustrative material, other than text, was prepared using black India ink drawings. Where multiple copies of the same drawing was needed for several frames offset plates were made and multiple copies run. These printed copies were then pasted in place on the appropriate frame masters. Mimeograph copies are not of uniform enough blackness to reproduce well and do not make readable copy. This same photoreproduction process was used to obtain multiple copies of one table which appears over and over again in the final test of Xenograde Systems. In this case each frame added one or more entry in the table. This was accomplished by cutting away a portion of the table for the early frames and cutting away less and less for subsequent frames. This procedure not only saved time but also assured accuracy by reducing possible type errors in reproducing the table.

Program Map. Determining the content of each frame on a particular film to assure the proper implementation of the branching procedure desired is a time-consuming and somewhat tedious process. This process as facilitated by making a program map for each version of the film to be made. This map was constructed on graph paper and contained the following information: (1) In one column appeared a sequence or frame number. This number appeared on its respective frame and was used as a way of finding difficulties or of locating a student's position on a particular film. Previously, films were made without sequence numbers and it was found that interpretation of the data was impossible. (2) The next column contained a code indicating the type of frame. In the Xenograde program this code indicated whether the frame was a presentation frame (P frame), feedback frame (F + or - frame), question frame (Q frame), etc. (3) The third column contained a list of the acceptable buttons. These were the letters of the buttons that are listed as options for the student to push on a given frame, e.g., if the frame is a P frame A, B, C, and D might all be possible buttons to press depending on the answer chosen. On the other hand, on a F - frame, only a C might be acceptable, since the instructions are to "push button C." (4) The fourth column contained the correct response. (5) The fifth column contained the code. This indicated whether it was possible for a student to return to the previous frame by pushing button R or whether only forward buttons would operate. This code corresponds to various positions of the black coding strip on the bottom of the frame. When completed, a program map had as many as 1200 to 1300 entries corresponding to the number of frames in the program. This included blank spacing frames which result from the spacing constraints of the Autotutor.

This program map was the blueprint for preparing the copy for filming. For every entry in the program map a copy frame was generated. After all of these frames had been prepared, a very careful check was made to be sure the frame contained the information exactly as it was recorded on the program map. Prior to the start of the program preparation, the program map was carefully checked several times to be sure there were no errors. The program map was the final word and errors in this map cannot be tolerated. This final editing was a tedious but crucial job. We found that it was better to check the entire set of film masters for one item of information at a time, rather than trying to check all at once, i. e., only sequence numbers were checked on the first pass through the material; on the second pass, only appropriate buttons were checked, etc.

Filming the Program.

While the preparation of the copy was very exacting the requirements of the actual filming were exasperating. Perhaps the following account will help future investigators avoid some of the pitfalls encountered. The following restrictions for Autotutor films all increase the difficulty in getting films properly made and processed: (1) Autotutors require double sprocketed, 35 mm, high high contrast, microfilm. (2) Frames must appear one to every four sprockets. (3) Printing must be done on a printer which guarantees exact registration. Ordinary microfilm printers have a tendency to let the print stock slip a little which means that the registration increases slightly, causing the frames of your program to drift across the lenscreen until finally after 150 or 200 frames, you are focused between two frames instead of on a particular frame. (4) Filming must be done with a camera which accepts double sprocketed film and which will expose a single frame at a time. There are some beautiful camers meeting this specification which sell for better than $10,000, and in our case this was a little beyond our budget. If someone should read this account with the intent of using the apparatus and procedures described, may we suggest that you copy the above paragraph and read it to your photographer at least three times. Chances are that he will still miss one or more crucial restrictions and assure you that your photographic needs are easily met by his laboratory. The awful day of realization will come when you look at that first print in your Autotutor (if it fits at all).

The most inexpensive way to meet our filming needs was to purchase and modify a used 35 mm Eyemo Bell and Howell movie camera. Ours was picked up for around $200, but it needed considerable overhauling before it was operational. This camera was mounted on an animation stand constructed by University technicians. The base of this stand contained an electronic circuit which operated a solonoid attached to the trigger of the camera in such a way that exposure was limited to a single frame at a time. The animation sheets were placed on some animation pins attached to the platform of the stand above which the camera is held in a fixed position sufficient to exactly frame the animation paper including the coding strip. One one corner of the platform was a button which was easily pressed by the palm of the hand. This button operated the camera exposing only one frame.

The filming procedure consisted of filming one frame at a time. The operator placed the animation paper in position, pressed the button on the platform, removed the sheet and repeated the process with the second sheet. To avoid confusion, even frames containing no text or illustrative material were actually exposed. An animation sheet with a number was photographed for such spacer frames. This procedure avoided confusion and allowed a fairly inexperienced photographer to produce reasonably acceptable copies. We found that occasionally a page was exposed twice or the camera was advanced without exposing a page but this happened only once or twice per 1000 frames, which is a reasonable error rate. When such errors in photographing did occur, however, the missing frame had to be refilmed and spliced into the negative and/or print before using in the Autotutor or additional frames had to be spliced out, all of which took time and caused delay.

Once the copy had been filmed, it was found that the equipment used to print copies for use in the Autotutors must have exact registration as explained above. Our films were printed on a 35 mm Cinema Printer, which had exact registration of negative and print. Reasonable results were obtained by using High Contrast Copy film and printing on positive Eastman fine grain duplicating film emulsion #73-66.

Filming difficulties and time schedule:

April 30, 1966. The University of Illinois Photographic laboratory informed us that they would be unable to film our materials during the month of May as scheduled and that their work load was such that filming during the entire summer would be impossible.

May 15, 1966. Xenograde material was prepared and ready for filming. All final editing and checking had been completed as explained above.

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*Appreciation is extended to Jim Walker, director of Brigham Young University Photo Studio and laboratory for his patience and diligence in helping us resolve the photographic problems encountered in preparing this material.

July 1966. University of Illinois administration voted to reject all outside contracts. It was no longer possible to film materials at the University of Illinois.

September 1, 1966. The principle investigator moved to Brigham Young University. Negotiations for transferring the contract to BYU were started early in the summer. Inquiry concerning the possibility of filming material at BYU were initiated during the summer. Assurance was received that BYU Photo services could produce the films.

September 1, 1966 until February 1, 1967. Contract negotiations continue. Contract was finally transferred February 1, 1967. Because money was not available during this period, it was impossible to begin filming. Copy sat ready in boxes.

February 15, 1967. Test film submitted to BYU Photographic Laboratory.

March 15, 1967. Four different test films had been completed. DISASTER. BYU was not equipped to film 35 mm, double sprocketed, micro film. They overlooked some of the restrictions. (See note above.)

March 15 through April 15, 1967. Negotiations were completed with the LDS Church Genealogical Society for filming. Result: they were not adequately equipped.

April 15 through May 15, 1967. Funds were secured through Brigham Young University, College of Education for the purchase of a special camera. A used camera was obtained May 4, 1967.

May 15 through December 1, 1967. The camera was being overhauled and the animation stand built during this period. The equipment was ready for operation December 1, 1967.

September 1, 1967 through September 1, 1968. The principle investigator served as visiting assistant professor, Stanford University. The contract was not transferred but left at BYU from where the author was on leave.

February 1, 1968. The first negatives were received from the BYU Photo Laboratory. All looked bright; however, printing registration did not operate correctly.

May 15, 1968. Printing problems were finally resolved. First adequate prints were received.

June 1, 1968 through August 1, 1968. The films were edited and checked. Many errors were present. Materials were prepared for correcting the errors. Summer vacation prevented further filming until fall.

September 1, 1968. The author returned to Brigham Young University.

October 15, 1968. Corrections were refilmed. Prints were requested from a California laboratory.

December 10, 1968. Prints were finally received. FILMS WERE FINALLY READY FOR DATA COLLECTION.

December 10 through December 19, 1968. DATA COLLECTION.

January 6 through January 18, 1969. DATA COLLECTION.

February 1 through March 28, 1969. DATA COLLECTION COMPLETED.

The previously-described calendar of events accounts for the very long duration of this rather easily-completed project.

APPENDIX B

DATA REDUCTION PROGRAM

COMPIL - main program

REDUCE - sub routine

by

Larry E. Wood

Prepared for compiling data punched directly from Techni-rite tapes when used with Autotutor teaching machines.

Brigham Young University

Summer 1967

DATA REDUCTION PROGRAM

I. Summary

The program consists of a main program named COMPIL and a subroutine called REDUCE. The main program analyzes and stores the response of each subject and then calls the subroutine which summarizes the data for each subject, causes it to be printed and also causes a data card(s) to be punched. These data cards can be indexed according to the experimental groups and submitted into a statistical program for further analysis. The program prints error messages indicating certain errors made in P-MAP preparations and data collection and preparation.

II. Setting up the program

A. P-MAP (program map) of every frame (except blank frames) of material seen by the subjects must be punched on I.B.M. cards in the following manner:

Column	
1 - 4	frame number
5	blank
6 - 7	type of frame in alphameric (1)
8	blank
9 - 18	legal responses in alphameric (2)
19	blank
20	correct response in alphameric
25 - 50	any identification helpful to the user

1. The type of frame index in the main program contains the following: X, C1, C2, F1, F2, Q1, Q2, P, SR, PU. Types may be assigned as desired so long as consistency is maintained and the following conditions are observed:
   a. Only types P, Q1, Q2 and SR may have multiple legal responses. All other types of frame must have only one response and it must be indicated as the correct answer.
   b. An R button may not be used as a legal incorrect response on a P, Q1, Q2 or SR frame. R's may be used on any frame as long as they represent the correct response.

c. When I button is legal and correct, then P frames and Q1 frames which follow the I or series of I buttons are recorded, both time and error count, as SR and Q2 respectively, even though the p-map identification is listed as P and Q1. When the program encounters a P frame or SR frame following a Q frame, the program then reverts to the frame type indicated on the p-map. e.g. typical sequence is as follows:

```
P     P     P     Q1     Q1     P     P

       I

            I
```

After first exposure subsequent presentations of P and/or Q1 are recorded as SR and/or Q2 respectively.

d. When R button is used to return S to a P and/or Q1 frame the second and all subsequent times and response data for that frame is recorded as SR and/or Q2.

2. Legal responses refer to the choices available to the subject. These may vary from one to ten. Regardless of the number, they must be punched in columns 9 - 18 as follows:

Column	Response
9	R
10	A
11	B
12	C
13	D
14	E
15	F
16	G
17	H
18	I

e. g. If "D" is the only legal response, it must be punched in column 13 and the rest must be left blank (9-12 & 14-18).

3. P-Map Identification. At the beginning of the p-map section when the program is submitted for a production run there must be a p-map identification card. In the first 76 columns, there may be any information thought valuable, such as lesson number, study number, etc., and in columns 77-80 there must be the number of the beginning frame of the p-map. There must not be any other identification cards in the p-map.

4. P-Map End Card. At the end of the p-map there must be a card with 9's punched in columns 1-4.

B. Data

Parameter Card. Data is submitted in groups of subjects which have seen the same material and therefore require the same p-map cards. At the beginning of each group of data requiring a particular p-map section, there must be a card punched in the following manner:

Column	
12 - 15	number of beginning p-map frame
16 & 17	blank
18 - 21	number of ending p-map frame

Following each group of data requiring a particular p-map section, there must be a card with 8's in columns 1 & 2, except for the last set of data, in which case the ending card must have 9's in the columns 1 and 2.

Data Cards. Each data card must be punched in the following manner:

Column	
1 & 2	card sequence (1)
3 & 4	lesson number
5 & 6	study number
7 & 8	experimental group number
9 & 10	subject number (must not exceed 88)
11 & 12	blank
13 - 16	time
17	response
18 - 20	time
21	response
. . .	. . .
77 - 79	time
80	response

1. Card sequence number refers to the number of each card required for each subject. As many cards as necessary may be used for each subject. If the responses for a particular subject end in the middle of a card, the rest of the columns may be left blank. Each card, however, must have the necessary identification numbers in columns 1-10.
2. When the program is submitted for a production run, it must be in the following sequence: main program, subroutine,

p-map with appropriate beginning and ending cards, data with appropriate beginning and ending cards.

C. Error messages

1. If the program fails to run because of an "illegal value for a computed go to" error message, one of two things may be wrong. There may be an illegal character in the type of frame column on one of the p-map cards. This error message may also be caused by an incorrect value in columns 12-15 of the card at the beginning of each set of data requiring a particular p-map. This error will terminate the program before execution.
2. If the p-map card is out of order, or if there is an incorrect frame number in columns 1-4 on a p- map card, the compil program will print an error message, "Cannot interpret p-map card." The frame number of the p-map card which is in error is then printed, and the program is terminated.
3. If the program cannot interpret a subject's responses, it will print an error message which says, "cannot interpret Card #___, response #___, frame #___." In this case, the program skips the remaining cards for that subject and goes to the next one.
4. If an "R" button has been punched twice on one of the data cards, the program will print an error message to this effect, and it will skip that particular subject and go to the new one.

III. Output

The program has two types of output.

A. Printed output consists of a table in which the subject number is listed down the left side. This number consists of four two-digit numbers where the first is lesson number, the second is study number, the third is group number, and the fourth is subject number. Headings include the following:

T-TIM = PTTIM + QTTIM

PTTIM = The cumulative time (in minutes) spent on P, C1, F1, and SR frames.

QTTIM = The cumulative time (in minutes) spent on Q1, Q2, PU, C2, F2, and X frames.

Those types of frames combined to produce this data can be modified by appropriate changes in program statements 1000, and 1001.

XTIM, C1TIM, C2TIM, F1TIM, F2TIM, Q1TIM, Q2TIM, PTIM, SRTIM, and PUTIM all contain the mean time per frame in seconds for each of the various types of frames indicated in the name. All time frames are output with F6.1 format.

PERR, SRERR, Q1ERR, and Q2ERR all contain the percent errors for the particular kind of frame indicated in the name. This percent is derived by dividing the total number of errors made on a particular kind of frame by the number of those frames seen by the student. All error frames are output with F6.4 format.

B. Punched card output consists of an eight digit ID number in columns 1 through 8. Digits 1 and 2 are the lesson number, 3 and 4 the study number, 5 and 6 the group number, and 7 and 8 the subject number. The following variables are punched in columns 14 through 79 of the first data card. T-TIM, PTTIM, QTTIM, XTIM, C1TIM, F1TIM, Q1TIM, PTIM, PUTIM, PERR, and Q1ERR. The time variables are F6.1 format, the error variables are F6.4 format. Decimals are punched in the cards.

The second data card has ID information in columns 1 - 8 and the following variables in columns 14-49. C2TIM, F2TIM, Q2TIM, SRTIM, SRERR, and Q2ERR. The time variables are F6.1 format and the error variables are F6.4 format. Decimals are punched in the cards.

IV. Register Index

1. P-MAP3. 1800 array containing type of frame (KR), possible choices for each frame or legal responses (LR), correct response (KOR), for every response.
2. LLR. Array into which LR values are stored after being converted to a power of 10.
3. TR. 1,34 array in which times and responses are from a single data card.
4. X, P, C1, F1, SR, C2, F2, Q1, Q2, PU. Types of frames seen.
5. R, A, B, C, D, E, F, G, H, I. Possible responses made by subjects.
6. XTIME (all extra frames), PTIME, CTIME, FTIME, SRTIME, CTIME2, FTIME2, QTIME1, QTIME2, PUTIME. Latencies for various frames.
7. PERR, SRERR, QERR1, QERR2. Errors for various types of responses.
8. ID (5). Card, study, lesson, group, and subject numbers.
9. KNTSUB. Subject counter.
10. JKOUNT and KKOUNT. Illegal response counters.
11. J. Counter used to index p-map and to move each subject through p-map comparison.
12. NF, KR, LR, KOR. See #1 (NF = Frame Number).
13. IDCHEK. Storage of subject number to be used in skipping a subject when necessary.
14. JSTART. Store beginning value of p-map section.

15. XFRAME, PFRAME, CFRAME, FFRAM1, SRFRAM, CFRAM2, FFRAM2, QFRAM1, QFRAM2, PUFRAM. Store number of various types of frames seen.
16. ENTEST. Store ending frame number of p-map section.
17. L. Do loop counter.
18. K. Response counter.
19. ILKONT. Illegal response counter.
20. CONRES. Store response after it is converted to a power of 10.
21. KK. (K=1)/2.
22. KNTFRA. Store current response for use in finding next value of J.
23. LASFRA. Store KNTFRA for future reference.
24. PTOTIM, QTOTIM, and TTIME. Total times for lesson, quiz and lesson plus quiz.
25. PATIME, XATIME, CATIM1, FATIME, SRATIM, CATIM2, FATIM2, QATIM1, QATIM2. Mean time frame for various types of frames.
26. PAERR, SRAERR, QAERR1. Errors for p-, SR and q-frames.
27. REPEAT, FTEST. Switches used to record P data as SR and Q1 data as Q2 when I button used.
28. RETURN. Switch used to record P data as SR and Q1 data as Q2 when R button used.

PRINTOUT

Data Reduction Program
Fortran Level 6
IBM 360/50
Larry E. Wood

```
      DIMENSION PMAP(1800,3),LR(10),LLR(10),AERR(20)
      DIMENSION TR(34)
      LOGICAL  REPEAT,FTEST,RETURN
      INTEGER X,C1,C2,F1,F2,Q1,Q2,P,SR,PU,R,A,B,C,D,E,F,G,H,ENTEST
      DATA X,C1,C2,F1,F2,Q1,Q2,P,SR,PU,R,A,B,C,D,E,F,G,H,I/1HX,2HC1,
     12HC2,2HF1,2HF2,2HQ1,2HQ2,1HP,2HSR,2HPU,1HR,1HA,1HB,1HC,1HD,1HE,1HF,
     2,1HG,1HH,1HI/
      COMMON XTIME,CTIME1,CTIME2,F[illegible]E1,FTIME2,QTIME1,QTIME2,PTIME,SRTIM
     1E,PUSTIM,XFRAME,CFRAM1,CFRAM2,FFRAM1,FFRAM2,QFRAM1,QFRAM2,PFRAME,S
     2RFRAM,PUSFRA,PERR,QERR1,QERR2,SRERR,KNTSUB,ID(5),JKOUNT,KKOUNT
C READ IN PROGRAM MAP STARTING WITH INITIAL VALUE OF J PUNCHED IN COLUMNS 77-80
C OF IDENTIFICATION CARD OF PMAP
      READ(5,150) J
  150 FORMAT (76X,I4)
  200 DO 400 L=1,10
      LR(L)=0
      LLR(L)=0
  400 CONTINUE
      READ (5,1) NF,KR,LR,KOR
    1 FORMAT (I4,1X,A2,1X,10A1,1X,A1)
      IF(NF.EQ.9999)GO TO 2
  202 IF(NF-J)5,6,7
    5 WRITE (6,201)J
  201 FORMAT (1X,48HCANNOT INTERPRET PMAP CARD. PROGRAM BEING DUMPED.1X,
     12HJ=I5)
      GO TO 20
C CONVERT ALPHAMERIC PMAP TO DIGITS
    6 IF(KR.EQ.X) KR=1
      IF(KR.EQ.X) GO TO 130
      IF(KR.EQ.C1) KR=2
      IF(KR.EQ.C1) GO TO 130
      IF(KR.EQ.C2) KR=3
      IF(KR.EQ.C2) GO TO 130
      IF(KR.EQ.F1) KR=4
      IF(KR.EQ.F1) GO TO 130
      IF(KR.EQ.F2) KR=5
      IF(KR.EQ.F2) GO TO 130
      IF(KR.EQ.Q1) KR=6
      IF(KR.EQ.Q1) GO TO 130
      IF(KR.EQ.Q2) KR=7
      IF(KR.EQ.Q2) GO TO 130
      IF(KR.EQ.P) KR=8
      IF(KR.EQ.P) GO TO 130
      IF(KR.EQ.SR) KR=9
      IF(KR.EQ.SR) GO TO 130
      IF(KR.EQ.PU) KR=10
  130 PMAP(J,1)=KR
      IF(LR(1).EQ.R) LLR(1)=10**0
      IF(LR(2).EQ.A) LLR(1)=10**1
      IF(LR(3).EQ.B) LLR(3)=10**2
      IF(LR(4).EQ.C) LLR(4)=10**3
      IF(LR(5).EQ.D) LLR(5)=10**4
      IF(LR(6).EQ.E) LLR(6)=10**5
      IF(LR(7).EQ.F) LLR(7)=10**6
      IF(LR(8).EQ.G) LLR(8)=10**7
      IF(LR(9).EQ.H) LLR(9)=10**8
      IF(LR(10).EQ.I) LLR(10)=10**9
      PMAP(J,2)=LLR(1)+LLR(2)+LLR(3)+LLR(4)+LLR(5)+LLR(6)+LLR(7)+LLR(8)+
     1LLR(9)+LLR(10)
      IF(KOR.EQ.R)PMAP(J,3)=1
      IF(KOR.EQ.R) GO TO 131
      IF(KOR.EQ.A) PMAP(J,3)=2
      IF(KOR.EQ.A) GO TO 131
      IF(KOR.EQ.B) PMAP(J,3)=3
      IF(KOR.EQ.B) GO TO 131
      IF(KOR.EQ.C) PMAP(J,3)=4
      IF(KOR.EQ.C) GO TO 131
      IF(KOR.EQ.D) PMAP(J,3)=5
      IF(KOR.EQ.D) GO TO 131
      IF(KOR.EQ.E) PMAP(J,3)=6
      IF(KOR.EQ.E) GO TO 131
      IF(KOR.EQ.F) PMAP(J,3)=7
      IF(KOR.EQ.F) GO TO 131
      IF(KOR.EQ.G) PMAP(J,3)=8
      IF(KOR.EQ.G) GO TO 131
      IF(KOR.EQ.H) PMAP(J,3)=9
      IF(KOR.EQ.H) GO TO 131
      IF(KOR.EQ.I) PMAP(J,3)=10
  131 J=J+1
      GO TO 200
    7 PMAP(J,1)=1
      PMAP(J,2)=1
      PMAP(J,3)=1
      J=J+1
      GO TO 202
C READ CONTROL CARD WITH PMAP START AND END FRAMES AND SUBJECTS IN GROUP.
    2 READ (5,4) JSTART,ENTEST,NUMSUB
    4 FORMAT (11X,I4,2X,I4,2X,I2)
C INITIALIZE
      KNTSUB=0
      IDCHEK=0
    8 XTIME=0.
      CTIME1=0.
      CTIME2=0.
      FTIME1=0.
      FTIME2=0.
      QTIME1=0.
      QTIME2=0.
      PTIME=0.
      SRTIME=0.
      PUSTIM=0.
      XFRAME=0.
      CFRAM1=0.
      CFRAM2=0.
      FFRAM1=0.
      FFRAM2=0.
      QFRAM1=0.
      QFRAM2=0.
      PFRAME=0.
      SRFRAM=0.
      PUSFRA=0.
      PERR=0.
      QERR1=0.
      QERR2=0.
      SRERR=0.
      KKOUNT=0
      JKOUNT=0
      RETURN=.FALSE.
      REPEAT = .FALSE.
      FTEST = .FALSE.
      J=JSTART
C READ DATA CARD
```

```
   10 READ (5,3,ERR=999) ID,TR
    3 FORMAT (5I2,2X,17(F3.0,F1.0))
   11 K=1
      IF(ID(5).EQ.IDCHEK) GO TO 10
      IF(ID(1)-88)21,2,20
   20 STOP
   21 DO 85 L=1,17
      ILKONT=0
      KR=PMAP(J,1)
      GO TO (31,32,33,34,35,36,37,38,39,40),KR
   31 XTIME=XTIME+TR(K)
      XFRAME=XFRAME+1.
      GO TO 41
   32 CTIME1=CTIME1+TR(K)
      CFRAM1=CFRAM1+1.
      GO TO 41
   33 CTIME2=CTIME2+TR(K)
      CFRAM2=CFRAM2+1.
      GO TO 41
   34 FTIME1=FTIME1+TR(K)
      FFRAM1=FFRAM1+1.
      GO TO 41
   35 FTIME2=FTIME2+TR(K)
      FFRAM2=FFRAM2+1.
      GO TO 41
      IF(RETURN) GO TO 37
   36 IF(REPEAT) GO TO 37
      IF (FTEST) GO TO 37
      QTIME1=QTIME1+TR(K)
      QFRAM1=QFRAM1+1.
      GO TO 41
   37 QTIME2=QTIME2+TR(K)
      QFRAM2=QFRAM2+1.
      RETURN=.FALSE.
      FTEST = .TRUE.
      REPEAT = .FALSE.
      GO TO 41
       IF(RETURN) GO TO 39
   38 IF (REPEAT) GO TO 39
      PTIME=PTIME+TR(K)
      PFRAME=PFRAME+1.
      FTEST = .FALSE.
      GO TO 41
   39 SRTIME=SRTIME+TR(K)
      SRFRAM=SRFRAM+1.
      FTEST = .FALSE.
      RETURN=.FALSE.
      GO TO 41
   40 PUSTIM=PUSTIM+TR(K)
      PUSFRA=PUSFRA+1.
C DECISION ABOUT CORRECT,INCORRECT, AND LEGAL RESPONSE
   41 IF(TR(K+1).LT.1.) REPEAT = .TRUE.
      IF(TR(K+1).LT.1.) TR(K+1) = 10
      IF(TR(K+1).EQ.PMAP(J,3)) GO TO 60
      IF(KR.LE.5.OR.KR.GT.9) GO TO 43
      TR1=TR(K+1)-1.
      CONRES=10.**(TR1)
      IF(CONRES.LT.1.) CONRES=1000000000.
   42 IF(CONRES.LE.PMAP(J,2).AND.CONRES.GT.1.) GO TO 50
C IF R IS A LEGAL RESPONSE, PROGRAM WILL DUMP SUBJECT
   43 IF(K.EQ.33) GO TO 47
   44 IF(TR(K+3).EQ.1.) GO TO 60
   45 KK=(K+1)/2
      IF(KNTSUB.LT.1)KKOUNT=1
      IF(KNTSUB.LT.1) GO TO 110
   49 WRITE (6,46) ID(1),ID(2),ID(3),ID(4),ID(5),KK,J
   46 FORMAT (/,1X,25HCANNOT INTERPRET CARD NO.,1X,5I3,1X,12HRESPONSE NO
     2.I3,1X,9HFRAME NO.I5)
      GO TO 48
   47 KNTFRA=TR(K+1)
      ILKONT=1
      READ (5,300,ERR=999) ID,TR
  300 FORMAT (5I2,2X,17(F3.0,F1.0))
      K=1
      IF(TR(K+1).EQ.1.) GO TO 65
      GO TO 45
   48 IDCHEK=ID(5)
      KNTSUB=KNTSUB+1
      GO TO 8
C STORE ERRORS
   50 GO TO (45,45,45,45,45,52,53,54,55,45),KR
   52 IF (REPEAT) GO TO 53
      IF (FTEST) GO TO 53
      IF(RETURN) GO TO 53
      QERR1=QERR1+1.
      GO TO 60
   53 QERR2=QERR2+1.
      FTEST = .TRUE.
      REPEAT = .FALSE.
      RETURN=.FALSE.
      GO TO 60
   54 IF(REPEAT) GO TO 55
      IF(RETURN) GO TO 55
      PERR=PERR+1.
      FTEST = .FALSE.
      GO TO 60
   55 SRERR=SRERR+1.
      FTEST = .FALSE.
      RETURN=.FALSE.
   60 KNTFRA=TR(K+1)
      IF(KNTFRA.LT.1) KNTFRA=10
   65 GO TO (70,71,72,73,74,75,76,77,78,79),KNTFRA
   70 RETURN=.TRUE.
      GO TO (90,91,92,93,94,95,96,97,98,99),LASFRA
   90 KK=(K+1)/2
      IF(KNTSUB.LT.1)KKOUNT=1
      IF(KNTSUB.LT.1)JKOUNT=1
      IF(KNTSUB.LT.1)GO TO 110
   89 WRITE (6,101) ID(1),ID(2),ID(3),ID(4),ID(5),KK,J
  101 FORMAT (/,1X,61HR BUTTON PUNCHED TWICE IN SUCCESSION. PUNCH ERROR
     1ON CARD NO.,1X,5I3,1X,12HRESPONSE NO.I3,1X,9HFRAME NO.I5)
      GO TO 48
   91 J=J-1
      GO TO 80
   92 J=J-3
      GO TO 80
   93 J=J-5
      GO TO 80
   94 J=J-7
      GO TO 80
   95 J=J-9
      GO TO 80
   96 J=J-11
      GO TO 80
   97 J=J-13
      GO TO 80
   98 J=J-15
      GO TO 80
   99 J=J+19
      GO TO 80
   71 J=J+1
      GO TO 80
   72 J=J+3
      GO TO 80
   73 J=J+5
      GO TO 80
   74 J=J+7
      GO TO 80
   75 J=J+9
      GO TO 80
   76 J=J+11
      GO TO 80
   77 J=J+13
      GO TO 80
   78 J=J+15
      GO TO 80
   79 J=J-19
   80 LASFRA=KNTFRA
      IF(J.EQ.ENTEST) GO TO 110
      K=K+2
   85 CONTINUE
      IF(ILKONT.EQ.1) GO TO 11
      GO TO 10
  110 CONTINUE
      CALL REDUCE
  111 CONTINUE
      IF(JKOUNT.EQ.1) GO TO 89
      IF(KKOUNT.EQ.1) GO TO 49
      KNTSUB=KNTSUB+1
      IDCHEK=ID(5)
      GO TO 8
  999 READ (5,998) AERR(1),AERR(2),ID(5),(AERR(I),I=3,20)
  998 FORMAT (2A4,I2,17A4,A2)
      WRITE (6,997) AERR(1), AERR(2),ID(5),(AERR(I),I=3,20)
  997 FORMAT(' PUNCH ERROR IN FOLLOWING DATA CARD',/1H ,2A4,I2,17A4,A2)
      GO TO 48
      END
C     SUBROUTINE REDUCE   SPECIFIC REVIEW
C
      SUBROUTINE REDUCE
      COMMON XTIME,CTIME1,CTIME2,FTIME1,FTIME2,QTIME1,QTIME2,PTIME,SRTIM
     1E,PUSTIM,XFRAME,CFRAM1,CFRAM2,FFRAM1,FFRAM2,QFRAM1,QFRAM2,PFRAME,S
     2RFRAM,PUSFRA,PERR,QERR1,QERR2,SRERR,KNTSUB,ID(5),JKOUNT,KKOUNT
      IF(KKOUNT.EQ.1) GO TO 120
 1000 PTOTIM=(2.5*(PTIME+CTIME1+FTIME1+SRTIME))/60.
 1001 QTOTIM=(2.5*(QTIME1+QTIME2+PUSTIM+CTIME2+FTIME2+XTIME))/60.
      TTIME=PTOTIM+QTOTIM
  706 IF(XFRAME.EQ.0) GO TO 507
      XATIME=(2.5*XTIME)/XFRAME
  707 IF(CFRAM1.EQ.0) GO TO 501
      CATIM1=(2.5*CTIME1)/CFRAM1
  701 IF(FFRAM1.EQ.0) GO TO 502
      FATIM1=(2.5*FTIME1)/FFRAM1
  702 IF(SRFRAM.EQ.0) GO TO 503
      SRATIM=(2.5*SRTIME)/SRFRAM
      SRAERR=SRERR/SRFRAM
  703 IF(CFRAM2.EQ.0) GO TO 504
      CATIM2=(2.5*CTIME2)/CFRAM2
  704 IF (FFRAM2.EQ.0) GO TO 505
      FATIM2=(2.5*FTIME2)/FFRAM2
  705 IF(QFRAM1.EQ.0) GO TO 508
      QATIM1=(2.5*QTIME1)/QFRAM1
      QAERR1=QERR1/QFRAM1
  708 IF(PUSFRA.EQ.0) GO TO 509
      PUATIM=(2.5*PUSTIM)/PUSFRA
  709 IF(PFRAME.EQ.0) GO TO 510
      PATIME=(2.5*PTIME)/PFRAME
      PAERR=PERR/PFRAME
  710 IF(QFRAM2.EQ.0) GO TO 511
      QATIM2=(2.5*QTIME2)/QFRAM2
      QAERR2=QERR2/QFRAM2
  711 IF(KNTSUB.GE.1) GO TO 122
      GO TO 120
  501 CATIM1=0
      GO TO 701
  502 FATIM1 = 0
      GO TO 702
  503 SRATIM = 0
      SRAERR = 0
      GO TO 703
  504 CATIM2 = 0
      GO TO 704
  505 FATIM2 = 0
      GO TO 705
  507 XATIME = 0
      GO TO 707
  508 QATIM1 = 0
      QAERR1=0
      GO TO 708
  509 PUATIM = 0
      GO TO 709
  510 PATIME=0
      PAERR=0
      GO TO 710
  511 QAERR2 = 0
      QATIM2=0
      GO TO 711
  120 WRITE(6,121)
  121 FORMAT(1H1,' SUBJECT T-TIM PTTIM QTTIM  XTIM C1TIM C2TIM F1TIM F2T
     2IM Q1TIM Q2TIM  PTIM SRTIM PUTIM   PERR SRERR Q1ERR Q2ERR')
      IF(KKOUNT.EQ.1) GO TO 140
  122 WRITE(6,123) ID(2),ID(3),ID(4),ID(5),TTIME,PTOTIM,QTOTIM,XATIME,CA
     2TIM1,CATIM2,FATIM1,FATIM2,QATIM1,QATIM2,PATIME,SRATIM,PUATIM,PAERR
     3,SRAERR,QAERR1,QAERR2
  123 FORMAT (/,1X,4I2,13(F6.1),1X,4(F6.4))
      WRITE(7,124) ID(2),ID(3),ID(4),ID(5),TTIME,PTOTIM,QTOTIM,XATIME,CA
     2TIM1,FATIM1,QATIM1,PATIME,PUATIM,PAERR,QAERR1
  124 FORMAT (4I2,5X,9(F6.1),2(F6.4))
      WRITE(7,125) ID(2),ID(3),ID(4),ID(5),CATIM2,FATIM2,QATIM2,SRATIM,S
     2RAERR,QAERR2
  125 FORMAT (4I2,5X,4(F6.1),2(F6.4))
  140 RETURN
      END
```

Appendix C

Task Analysis Test No. 1

This test was devised to evaluate the following hierarchical list of behaviors.

Table 1

Behavioral sequence necessary to solve problems requiring the student to supply the numerical and verbal name of a fractional part of a whole object or group of objects.

I. Identify the set under consideration.

II. Identify the number of elements in the entire set.

III. Identify the subset.

IV. Identify the number of elements in the subset.

V. Write the numeral indicating the number of elements in the entire set under the line.

VI. Write the numeral indicating the number of elements in the subset over the line.

VII. Say the number of elements in the subset as a numeral.

VIII. Say the number of elements in the entire set as an ordinal.

I. IDENTIFY THE SET

1. You have 3 marbles and 3 balls. Tom wants 1 marble and Bill wants 1 marble. What will you have to share with your friends:

a. Balls b. Marbles c. Tom and Bill d. Nothing

2. Mother has a cake and some cookies. She says you and your brother can have some cake. What will you and your brother have part of?

a. Cake b. Cookies c. Mother d. I don't know

3. The teacher has some chalk, pencils and pens. She says you must pass out the pencils. Each person in the class will get part of what?

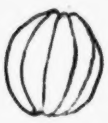
a. Chalk b. Pencils c. Pens d. Erasers

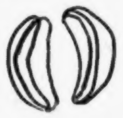
II. COUNT THE ELEMENTS

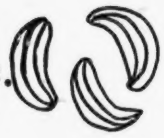
1. Counting yourself, there are 4 children in your reading group. If each child needs a piece of paper, but you only have one large piece, how many pieces will you cut the big sheet of paper into?

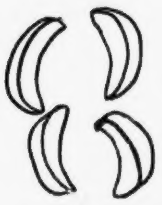
a. 4 b. 3 c. 5 d. 0

2. You give one orange to your two brothers. They cut it so that each has the same amount. What will the orange look like when it is cut?

a. 

b. 

c. 

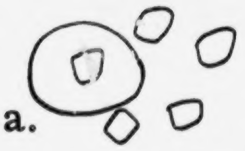
d. 

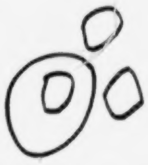
3. Mother makes a pie and tells you to cut it so each person in the family has a piece and none is left over. If you have 1 brother, 1 sister, 1 mother and 1 father, how many pieces will be cut?

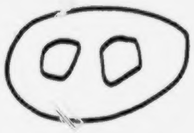
a. 4 b. 5 c. 2 d. none

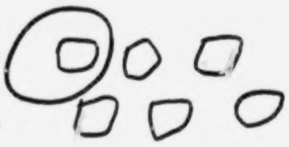
III. IDENTIFY THE SUBSET

1. You want one piece of candy and there are 5 pieces on the table. Which picture has a circle drawn around the part you want?

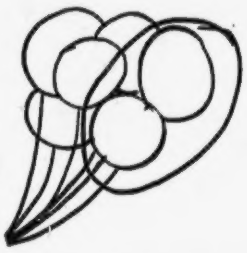
a. 

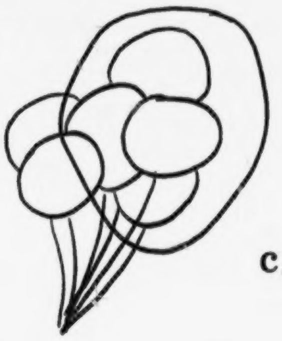
b. 

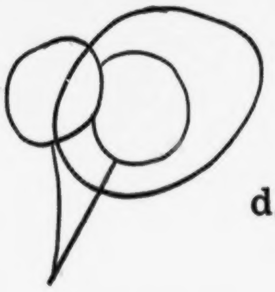
c. 

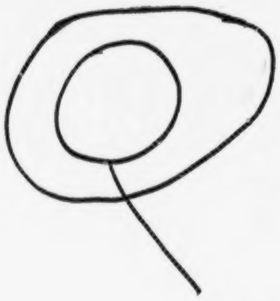
d. 

2. There are 6 balloons and you and your brother buy 2. Which picture has a circle drawn around the balloons you and your brother buy?

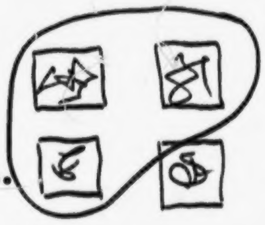
a. 

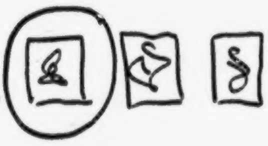
b. 

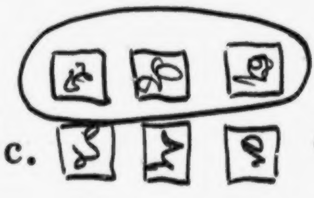
c. 

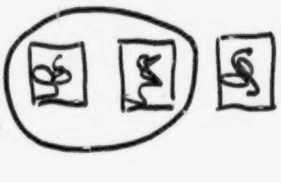
d. 

3. You have 4 stamps. You give Mother 3. Which picture shows the part that you give to Mother?

a. 

b. 

c. 

d. 

IV. ELEMENTS IN SUBSET (COUNT)

1. If a pie is cut into 4 pieces and you and your brother share it so you each have the same number of pieces, how many will you have?

a. 1 b. 2 c. 3 d. 4

2. Mother gives you 10 marbles to share with your friend Jim. If you each have the same amount, how many will Jim get?

a. 3 b. 5 c. 9 d. 10

3. A big rug is cut into 4 small rugs. Mother puts 2 in the kitchen, 1 in the hall, and gives one to you. How many go in the kitchen and the hall?

a. 2 b. 3 c. 4 d. 1

V. WRITE NUMBER OF ELEMENTS UNDER THE LINE

1. Your mother cuts an apple into 5 slices and gives you 3 slices. When you write the fraction for the part that you get, which number goes under the line?

a. /3 b. /2 c. /5 d. /8

2. Bill has 6 cards and gives his brother 2 cards and his sister 4 cards. When you write the fraction for the part that his brother gets, which number is under the line?

a. /2 b. /4 c. /6 d. /12

3. An orange has 4 parts to it. You eat 3 parts. What number goes below the line when you write the fraction of the orange that you eat?

a. /3 b. /4 c. /7 d. /1

VI. WRITE SUBSET ELEMENTS OVER LINE

1. Mother has 6 eggs. She gives 1 to you, 2 to father, 1 to sister, and she eats 1. When you write the fraction for the part of the eggs that you get, what number goes over the line?

a. 3/ b. 0/ c. 1/ d. 2/

2. There are 5 pieces of candy. You take 2 pieces. When you write the fraction which tells you how much candy you took, what number goes over the line?

a. 5/ b. 2/ c. 3/ d. 1/

3. Dad has 7 pennies to give you and your brother. He gives 3 to you and 4 to your brother. When you write the fraction of the pennies that you get, what number goes above the line?

a. 3/ b. 4/ c. 7/ d. 1/

VII. WRITE THE FRACTION

1. Mother has 6 eggs. She gives 2 to you, 2 to father, and 1 to sister. What fraction of the eggs will father get?

a. 1/6 b. 2/6 c. 5/6 d. 2

2. Jim has 5 balls. He gives 4 balls to you. He keeps 1. What fraction of the balls does he keep?

a. 1/5 b. 4/5 c. 1 c. 5/1

3. There are 4 apples. You eat 3. What fraction of the apples do you eat?

a. 3 b. 3/4 c. 1/4 d. 4

VIII. SAY FRACTIONS

1. Your mother cuts an apple into 5 slices and gives you 3 slices. How much of the apple will you get?

a. three-fifths b. five-thirds c. 3-fifths d. two-thirds

2. Bill has 6 playing cards. One of the cards is a spade. One is a heart, and four are diamonds. What fraction of the cards are not diamonds?

a. one-sixth b. two-sixths c. four-sixths d. one-fifth

3. Bill has 4 marbles. Three are red and one is black. What fraction of the marbles are red?

a. three b. three-fourths c. one-fourth d. three-fifths

Appendix D

Task Analysis Test No. 2

This test was devised to evaluate the following hierarchical list of behaviors.

Table 2
Experiment II - Part 2

Hypothesized Hierarchy
of Fundamental Concepts of Fractions

Level C	The student will be able to write non unit fractional parts in numerals, e. g., 2/3 3/4, 7/8, etc.	NON UNIT NUMBER-NAMER IN NUMERALS
Level B	The student will be able to write how many parts, i. e., the numberator, for non unit fractions, e. g., two thirds, three fourths, etc.	NON UNIT NUMBER-NAMER
Level A2	The student will be able to write the appropriate word for one piece or one part other than one half, e. g., one third, one fourth, etc.	UNIT NAMER
Level A1	The student will be able to write the appropriate word for one piece or part when this is one half.	ONE HALF

It appears that the logical hierarchical analysis in table 2 is fairly representative. The experimental program was revised to follow this hierarchical structure.

NAME__________________ GRADE____________________

TEACHER_______________ DATE______________________

DIRECTIONS:

ANSWER THESE QUESTIONS BY FILLING IN THE BLANK.

USE WORDS TO WRITE THE ANSWER.

EXAMPLE:

BOB HAS A CANDY BAR. HE CUTS IT INTO 2 PIECES. 1 PIECE WOULD BE ____________ _____________ OF THE WHOLE CANDY BAR.

WRITE THE WORDS ONE HALF IN THE BLANKS.

DIRECTIONS: USE WORDS TO WRITE THE ANSWERS.

1. Sally has an apple. She cuts it into 3 pieces. Each piece is ________ ________ of the whole apple.
2. Tom has a pear. He cuts it into 2 equal pieces. Each piece is ________ ________ of the whole pear.
3. A whole cake is cut into 4 equal pieces. 1 piece would be ________ __________ of all the whole cake.
4. Margie has 8 pieces of chocolate candy. 1 of the pieces would be ________ __________ of the candy.
5. Mary buys 4 balloons at the circus. She gives 1 balloon to her brother Bill. Bill has ________ __________ of all of the balloons.

DIRECTIONS: USE WORDS TO WRITE THE ANSWERS.

6. A whole watermelon is cut into 7 equal pieces. 1 of the pieces would be ________ __________ of all of the watermelon.

7. Mother bakes 3 pies. 1 pie would be ________ __________ of all of the pies.

8. Jimmy has 2 toy soldiers. 1 toy soldier is ________ __________ of all of the toy soldiers.

9. An orange is cut into 8 equal pieces. 1 piece would be ________ __________ of the whole orange.

10. There are 7 eggs in the refrigerator. 1 egg would be ________ __________ of all of the eggs.

DIRECTIONS: USE WORDS TO WRITE THE ANSWERS.

11. Jill has 3 pencils. She gives 2 pencils to her brother. She gives ________ __________ of all her pencils away.

12. Sally has 8 pieces of gum. She gives 4 pieces to Jane. Jane has ________ __________ of all the gum.

13. Mother cuts a loaf of bread into 7 pieces. 2 of the pieces would be ________ __________ of all the bread.

14. Mother cuts a grapefruit into 4 parts. 3 of the parts would be ________ __________ of the whole grapefruit.

15. Mike has 7 toy airplanes. He gives 2 airplanes to his brother. Mike gives ________ __________ of all his airplanes away.

DIRECTIONS: USE WORDS TO WRITE THE ANSWERS.

16. Mother has 4 cupcakes. She gives Bill 2 cupcakes. She gives Bill ________ __________ of all the cupcakes.

17. Father has a board. He saws it into 4 equal pieces. 2 of the pieces would be ________ __________ of the whole board.

18. Father buys 4 donuts and he eats 3 of them. Father ate ________ __________ of all the donuts.

19. Betty bakes an apple pie. She cuts it into 3 equal pieces. She eats 2 pieces. Betty ate ________ __________ of the whole pie.

20. Father buys a pizza pie. He cuts it into 8 pieces. 4 of the pieces would be __________ __________ of all the pizza.

PART II

DIRECTIONS:

ANSWER THESE QUESTIONS BY FILLING IN THE BLANK. THIS TIME USE NUMBERS TO WRITE IN THE ANSWER.

EXAMPLE:

BOB HAS A CANDY BAR. HE CUTS IT INTO 2 PIECES. 1 PIECE WOULD BE ______________OF THE CANDY BAR.

WRITE THE NUMBERS 1/2 IN THE BLANK.

DIRECTIONS: USE NUMBERS TO WRITE THE ANSWERS.

21. James has 3 marbles. He gives 2 marbles away. He gives __________ of all his marbles away.

22. Mother has 7 cupcakes. She gives 4 cupcakes to the children. The children get __________ of all of the cupcakes.

23. Billy has 4 baseballs. He loses 2 baseballs. Billy loses __________ of all his baseballs.

24. A cake is divided into 8 equal pieces. 6 pieces would be __________ of the whole cake.

25. Jane slices a banana into 7 equal pieces. She puts 6 slices on her cereal. She puts __________ of the whole banana on her cereal.

DIRECTIONS: USE NUMBERS TO WRITE THE ANSWERS.

26. John has some clay. He cuts it into 4 equal pieces. He gives 2 pieces of clay to a friend. He gives __________ of all his clay away.

27. Mother has some cloth. She cuts it into 4 equal pieces. 3 pieces would be __________ of the whole piece of cloth.

28. Mother bakes a cake. She cuts it into 3 equal pieces. She gives Father 2 pieces. Father eats __________ of the whole cake.

29. Kim has 4 blocks. 3 of them would be __________ of all of the blocks.

30. Mother has 8 buttons. She sews 2 buttons on a dress. She sews __________ of all the buttons on the dress.